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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

TRANSACTIONS

VOL. I.

1852 & 1853.

NEWCASTLE-UPON-TYNE.

1853.

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INDEX.

List of Patrons.

Meeting of Colliery Owners, Viewers, &c., in the Coal Trade Office, July 3rd, 1852.

Report of Committee.

Rules.

Proceedings at General Meeting, August 21st, 1852.

Ditto Ditto, September 3rd, 1852.

List of Names of Officers of the Institution.

Inaugural Address, by the President.

Proceedings at General Meeting, October 1st, 1852.

The Steam Jet as a Motive Power, by J. A. Longridge, Esq.

Proceedings at General Meeting, November 5th, 1852.

Ditto Ditto, December 13th, 1852.

Experiments on the Relative Value of the Furnace and Steam Jet, by Nicholas Wood, Esq.

An Address on the Relative Value of the Furnace and Steam Jet as Ventilating Powers, by Wm. Armstrong, Jun., Esq.

Proceedings at Council Meeting, December 31st, 1852.

Ditto at General Meeting, February 4th, 1853.

Experiments to determine the Relative Value of the Furnace and Steam Jet as Ventilating Powers, by Wm. Barkus, Esq., Thos. J. Taylor, Esq., and Matthew B. Robson, Esq.

Proceedings at General Meeting, March 4th, 1853.

Ditto Ditto, April 1st, 1853.

Ditto Ditto, May 6th, 1853.

On the Ventilation and Gases of Coal Mines, &c., by Wm. Barkus, Esq.

Proceedings at General Meeting, June 3rd, 1853.

Ditto Ditto, July 1st, 1853.

Ditto Ditto, August 5th, 1853.

Proofs of the Subsistence of the Fire-Damp of Coal Mines in a State of High Tension in Situ, &c., by Thos. J. Taylor, Esq.

On Safety Lamps for Lighting Coal Mines, by Nicholas Wood, Esq.

On the Safety Lamp for the use of Coal Miners, by T. Y. Hall, Esq.

210903

PATRONS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

His Grace the Duke of Northumberland.

The Most Noble the Marquis of Londonderry.

The Right Honourable the Earl of Lonsdale.

The Right Honourable the Earl Grey.

The Right Honourable the Earl of Durham.

The Right Honourable Lord Wharncliffe.

The Right Honourable Lord Ravensworth.

The Right Reverend the Lord Bishop of Durham.

The Very Reverend the Dean and Chapter of Durham.

The Venerable Archdeacon Thorpe, the Warden of Durham University.

Wentworth B. Beaumont, Esq.

AT a Meeting of Colliery Owners, Viewers, and others interested in the Coal Trade, held in the Coal Trade Office, Newcastle, on Saturday, 3rd of July, for the purpose of forming a Society, to meet at fixed periods and discuss the means for the Ventilation of Coal Mines, for the Prevention of Accidents, and for General Purposes connected with the Winning and Working of Collieries.

The Meeting was attended by the following gentlemen :—

Messrs. WM. ANDERSON.
NICHOLAS WOOD.
T. E. FORSTER.
WM. BARKUS, Sen.
WM. BARKUS, Jun.
C. ANDERSON.
JOHN ROBSON.
D. JONASSOHN.
GEO. ELLIOT.
H. T. MORTON.
THOS. CRAWFORD, Sen.
THOS. CRAWFORD, Jun.
JNO. TAYLOR.
MATTHIAS DUNN.
EDWD. POTTER.
THOS. JOBLING.
T. C. MAYNARD.
STEPHEN REED.
R. H. PHILLIPSON.
HENRY LONGRIDGE.
EDWD. SINCLAIR.
WM. HUNTER.
T. Y. HALL.
R. S. JOHNSON.
JOS. SMITH, Jun.
J. R. LIDDELL.
WM. WATSON.
GEO. CLARK.
THOS. WOOD.
WM. STOBART.
THOS. DOUGLAS.
JOHN DAGLISH.
CUTHBERT BERKLEY.
SANDIMAN REID.
T. C. HURST.
JOHN RUTHERFORD.
JOHN SOUTHERN.
GEORGE SOUTHERN, Jun.
SEPTIMUS BOURNE.
WILLIAM SPENCER, Jun.
G. C. GREENWELL.
A. PALMER.
R. SIMPSON.
— RAWSTHORNE.

WM. ANDERSON, Chairman.

The following Resolutions were proposed and carried unanimously :—

Proposed by Mr. D. Jonassohn, and seconded by Mr. T. E. Forster,

That a Society be formed of Coal Owners, Viewers, and others interested in Collieries, to meet at fixed times to discuss the means for the Ventilation of Collieries, for preventing Accidents, and for general purposes connected with the Winning and Working of Collieries.

Proposed by Mr. Geo. Elliot, and seconded
by Mr. John Robson,

That this Society be called "The North of England Society, for the Prevention of Accidents, and for other purposes connected with Mining."

Proposed by Mr. Nicholas Wood, and seconded
by Mr. T. C. Maynard,

That a Committee be appointed, consisting of Messrs. E. Potter, John Robson, Nicholas Wood, William Anderson, George Elliott, William Barkus, Sen., William Barkus, Jun., M. Dunn, John Taylor, T. C. Maynard, George C. Greenwell, T. C. Hurst, T. E. Forster, Thomas Crawford, Sen., Thomas Crawford, Jun., T. J. Taylor, William Armstrong, John Johnson, Thomas Jobling, H. T. Morton, with power to add to their number, to draw up rules for the regulation of the Society, and to report to an adjourned meeting to be held in this Office, on Saturday, July 31st, at 3 o'clock p.m.

Proposed by Mr. T. E. Forster, and seconded
by Mr. William Hunter,

That Mr. Edward Sinclair be appointed Honorary Secretary.

WM. ANDERSON, *Chairman.*

ADVERTISEMENT.

The Institution is not, as a body, responsible for the facts and opinions advanced in the following Papers read, and of the Abstracts of the Conversations which occurred at the Meetings during the Session.

REPORT.

Coal Trade Office, Newcastle, July 24th, 1852.

The Committee appointed on July 3rd, have annexed to this Report, a draft of the Rules prepared, and now recommended by them, for the government of the proposed North of England Society for the Prevention of Accidents in Mines, and for the Advancement of Mining Science generally.

It does not appear necessary for the Committee to enlarge upon the objects of the Society, which are already so well understood by the Meeting. Their remarks will, therefore, be confined mainly to questions of financial detail.

It must be obvious, that the Society will require to be sustained by adequate funds; especially as so many branches of science are connected directly, and indirectly, with Mining—involving, it may be, the purchase of expensive apparatus—the construction of models—and the prosecution of such particular courses of experiment and research as fall legitimately within the province of the proposed Society, and which may, together with a library of scientific works, be deemed essential to its success.

Suitable apartments for the use of the Society will also be required.

It seems advisable, however, to defer carrying out these arrangements until the means at the disposal of the Society shall be more clearly ascertained.

The annual subscription of ordinary Members is recommended to be £2 2s.; but the Committee submit, that the subscription from this source alone will prove inadequate to meet an expenditure sufficiently large to render the Society really effective. The Committee would therefore respectfully suggest, that the deep interest which must be felt by the Trade

in an institution of this nature, one of the results of which may be a material reduction in the expense of Mining operations, might justify the appropriation of a fund, calculated to render the Society, in a great measure, independent of the more precarious sources of support, arising out of the annual subscriptions of individual Members.

The Committee therefore trust, that the meeting will take this very essential part of the subject into consideration; and that the Trade will be induced to further the objects of the Society, by a provision calculated to render it permanently useful and prosperous, and to make it rank in a manner, to which this district is fairly and peculiarly entitled, with other institutions of a scientific character throughout the kingdom.

The Committee would perhaps step beyond the line of their duty in suggesting the particular mode of raising the funds in question; but they may state, that the probable current expence of properly conducting the Society cannot be estimated at less than from £400 to £500 a-year: and assuming the permanent number of paying Members to be 100, a deficiency of between £200 and £300 a-year would thus require to be made up.

WM. ANDERSON, *Chairman.*

RULES

OF

THE NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS, &c.

1.—That the Members of this Society shall consist of Ordinary Members, Life Members, and Honorary Members.

2.—That the Annual Subscription of each Ordinary Member shall be £2 2s., payable in advance, and that the same shall be considered as due and payable on the first Saturday of August in each year.

3.—That all persons who shall at one time make a donation of £20 or upwards, shall be Life Members.

4.—Honorary Members shall be persons who shall have distinguished themselves by their literary or scientific attainments, or made important communications to the Society.

5.—That a General Meeting of the Society shall be held on the first Friday of every month, at 2 o'clock p.m., and the General Meeting in the month of August shall be the Annual Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year, shall be presented by the Council. A Special Meeting of the Society may be called whenever the Council shall think fit, and also on a requisition to the Council signed by ten or more Members.

6.—No alteration shall be made in any of the Laws, Rules, or Regulations of the Society, except at the Annual General Meeting, or at a Special Meeting; and the particulars of every alteration to be then proposed shall be announced at a previous General Meeting, and inserted in its minutes, and shall be exhibited in the Society's meeting-room, fourteen days previously to such General Annual or Special Meeting.

7.—Every question which shall come before any Meeting of the Society, shall be decided by the votes of the majority of the Ordinary and Life Members then present and voting.

8.—Persons desirous of being admitted into the Society as Ordinary or Life Members, shall be proposed by three Ordinary or Life Members, or both, at a General Meeting;—the proposition shall be in writing, and signed by the proposers, and shall state the name and residence of the individual proposed, whose election shall be balloted for at the next following General Meeting, and during the interval, notice of the proposition shall be exhibited in the Society's Room. Every person proposed as an Honorary Member must be recommended by at least five Members of the Society, and elected by ballot at the General Meeting next succeeding. A majority of votes shall determine every election.

9.—The Officers of the Society shall consist of a President, four Vice-Presidents, and twelve Members, who shall constitute a Council for the direction and management of the affairs of the Society; and of a Treasurer, and a Secretary; all of whom shall be elected at the Annual Meeting, and shall be re-eligible. Lists containing the names of all the persons eligible having been sent by the Secretary to the respective Members, at least a month previously to the Annual Meeting, the election shall take place by written lists, to be delivered by each voter in person to the Chairman, who shall appoint scrutineers of the lists; and the scrutiny shall commence on the conclusion of the other business of the Meeting. At meetings of the Council, five shall be a quorum, and the record of the Council's proceedings shall be at all times open to the inspection of the Members of the Society.

10.—The Funds of the Society shall be deposited in the hands of the Treasurer, and shall be disbursed by him, according to the direction of the Council.

11.—The Council shall have power to decide on the propriety of communicating to the Society, any papers which may be received, and they shall be at liberty, when they think it desirable to do so, to direct that any paper read before the Society shall be printed. Intimation shall be given at the close of each General Meeting of the subject of the paper or papers to be read, and of the questions for discussion, at the next meeting, and notice thereof shall be affixed in the Society's room ten days previously. The reading of papers shall not be delayed beyond 3 o'clock, and if the election of Members or other business should not be sooner dispatched, the President may adjourn such business until after the discussion of the subject for the day.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

HELD IN THE COAL TRADE OFFICE, NEWCASTLE-UPON-TYNE, ON SATURDAY, AUGUST 21ST, 1852,

NICHOLAS WOOD, ESQ., CHAIRMAN.

THE proceedings of the last Meeting having been read, the Secretary reported a donation of Twenty Pounds from Edward Shipperdson, Esq., of Durham.

Resolved, that the thanks of the Meeting be given to Edward Shipperdson, Esq., and that his name be enrolled in the books of the Society as a Life Member.

The Meeting then proceeded to the Election of Officers, when the following names were returned :—

President.

NICHOLAS WOOD, ESQ.

Vice Presidents.

THOMAS JOHN TAYLOR, ESQ.
THOMAS E. FORSTER, ESQ.
WILLIAM ANDERSON, ESQ.
EDWARD POTTER, ESQ.

Council.

Messrs. THOMAS JOBLING,
JOHN ROBSON,
GEORGE ELLIOTT,
WILLIAM BARKUS, Sen.
T. CRAWFORD, Jun.
H. T. MORTON,
WILLIAM ARMSTRONG,
CHARLES CARR,
JOHN TAYLOR,
SANDIMAN REID,
G. C. GREENWELL,
J. A. LONGRIDGE.

Treasurer.

MR. EDWARD BOYD.

Secretary.

MR. EDWARD SINCLAIR.

Moved by JOHN ROBSON, Esq., seconded by THOMAS STOREY, Esq., and resolved,

That the proceedings of this Meeting, together with a list of the Officers, be printed, and a copy sent to each Member; and also that they be published in the Newcastle, Gateshead, Durham, and Sunderland newspapers.

NICHOLAS WOOD, CHAIRMAN.

ERRATA.

In Page opposite, for Matt. Hindhaugh, read Nath. Hindhaugh.

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS,

MONTHLY MEETING, FRIDAY, SEPT. 3RD, 1852, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

Messrs. Matthias Dunn and Goldsworthy Gurney were elected Honorary Members of the Institution, and Messrs. Matt. Hindhaugh, John Walker, Richard Lamb, James Joicey, John Joicey, and William Kimpster were elected ordinary Members.

On the motion of Edward Potter, Esq., seconded by William Armstrong, Esq., it was resolved,

That each Member of the Society be empowered to introduce a stranger at any of the General Meetings of the the Society.

The President then read an Inaugural Address; after which the Meeting was adjourned until Friday, October 1st.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

INAUGURAL ADDRESS

DELIVERED TO THE MEMBERS

OF THE

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS AND OTHERS INTERESTED IN THE PREVENTION OF ACCIDENTS IN MINES, AND IN THE ADVANCEMENT OF MINING SCIENCE GENERALLY,

AT

NEWCASTLE-ON-TYNE,

SEPT. 3rd, 1852,

BY

NICHOLAS WOOD, ESQ.,

MEMBER OF THE INSTITUTE OF CIVIL ENGINEERS, FELLOW OF THE GEOLOGICAL SOCIETY, MINING ENGINEER, AND

PRESIDENT OF THE SOCIETY.

Durham:
PRINTED AT THE OFFICE OF WILLIAM AINSLEY,
SADDLER STREET.

1852.

The North of England Institute of Mining Engineers, and others interested in the prevention of Accidents in Mines, and in the advancement of Mining Science generally.

PRESIDENT.

NICHOLAS WOOD, Esq.

VICE-PRESIDENTS.

THOMAS JOHN TAYLOR, Esq.
THOMAS E. FORSTER, Esq.
WILLIAM ANDERSON, Esq
EDWARD POTTER, Esq.

COUNCIL.

Messrs. Thomas Jobling	T. Crawford, Jun.	John Taylor
John Robson	H. T. Morton	Sandiman Reed
George Elliot	William Armstrong	G. C. Greenwell
William Barkus, Sen.	Charles Carr	J. A. Longridge

TREASURER.

Mr. EDWARD F. BOYD.

SECRETARY.

Mr. EDWARD SINCLAIR.

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INAUGURAL ADDRESS.

GENTLEMEN,—

In delivering the first address to the Society at the commencement of your labours, I must beg to congratulate the members thereof, on the progress which they have made in so short a time, towards the establishment of the Society.—The association together of upwards of eighty members—the appointment of officers—and the subscription of an amount of funds, which however small is still what may be deemed sufficient for a commencement,—all point towards success. Let us not, however, deceive ourselves. We have only cut the first sod, or laid the foundation stone; the whole of the works or the edifice has yet to be reared, the resources developed, and the ultimate objects attained.

While therefore you have done me the honor to select me to preside over your labours and deliberations, bear in mind that it is only by unremitting perseverance—by the continued exercise of our united and combined efforts, that we can be successful. We must each of us act as if we were individually responsible for the success of the Institution; and with such efforts, and actuated by such feelings, there can be no doubt that we shall be successful.

We have, I think (except the Funds of which I shall speak hereafter,) within us all the elements of success; and supported as I have no doubt we shall be in respect of Funds if we act true to ourselves, and to the objects for which we are associated together, we may hope that to-day we are entering upon an undertaking which may be of essential utility to the important interests entrusted to our charge, and which may be the means of averting some at least of those dreadful and deplorable catastrophes which have too often been felt with

such disastrous consequences to the distressed, and to the sufferers by their occurrence: and that it may be the means of raising the profession to a higher standard of intelligence in Literature and Science, than it has hitherto attained.

The object of the Institution is twofold.—

First.—By a union or concentration of professional experience, to endeavour if possible, to devise measures which may avert or alleviate those dreadful calamities, which have so frequently produced such destruction to life and property, and which are always attended with such misery and distress to the Mining population of the District; and—

Secondly.—To establish a Literary Institution more particularly applicable to the theory, art, and practice of Mining, than the Institutions in the locality present, or which are within the reach of the profession in this locality.

While therefore, we propose that the Institution should practically consist of members of the profession of Mining Engineers, and that it should be substantially of a Literary character, we have thought it advisable to extend the range of its objects and labours, and we have consequently opened its doors to the admission of persons interested in the prevention of Accidents in Mines, and in the advancement of Mining Science generally.

We are aware that this admits of a very extensive application, for who is not interested, if for no other object, from feelings of humanity, in the prevention of Accidents in Coal Mines?

Our intention is however, not to employ the terms in so extensive a meaning. We should be very glad to have the support of any individual in so desirable an object, from whatever motives or feelings he may be actuated; but we wish the principles of the Institution to be understood—it is an Institution of practical miners associated together, to endeavour by a combination of practical knowledge—by an interchange of practical experience—and by a united and combined effort, to improve ourselves in the science of our profession, and by acting together as a body, we may be the instruments of preventing as much as practicable, the recurrence of those

dreadful catastrophes to which I have alluded; and at the same time, to raise the art and science of Mining to its highest practicable scale of perfection, in safety, economy, and efficiency.

Our Institution is in the first place, therefore, intimately connected with the interests of all the Proprietors of coal, and all the Lessees of Mines of this district; or what is generally termed, the Coal Owners of the North. Our claims to their support are all powerful. We are associated together for the prevention of Accidents in Mines. Who so interested in the prevention of Accidents as Coal Owners? Past experience shews that they are never behind the most energetic philanthropist in attention, and care, to the sufferings of the injured, or victims of those dreadful accidents, or in alleviation of the misery and distress of their relatives or families; on this ground alone, we seek to have their support. But we are also associated together for the improvement of the art of Mining scientifically, practically, and economically. The Coal Owner, or worker of the coal is therefore on that account likewise most materially interested in the success of the Institution. And as one of the prominent features of the Institution, is to endeavour to accomplish the best and most perfect mode of abstracting the coal, so as to produce the largest quantity of coal out of a given area of mine, the Proprietor of the coal, as well as the Worker of it, is no less materially interested in the success of the Institution.

Considering, therefore, that we have paramount claims upon the representatives of those interests for support and assistance, we have consequently opened our doors to the admission of gentlemen of both those denominations; and we humbly solicit their support and co-operation in the one or other, or in both of those characters. We should likewise be glad to have numbered amongst our members, or as supporters of the Institution, any literary, scientific, or practical members of other Institutions, professions, or occupations, whose labours, talents, or professional experience, can in any way aid our efforts, in the accomplishment of the objects of the Institution, either in the prevention of accidents, or in perfecting the art of Mining.

With these general observations on the principles upon which the Institution is founded, I shall now proceed to point out more in detail, an outline of the subjects which we shall have to consider—the range and scope of the studies embraced within our Constitution—

and the branches of Science which it is intended to grapple with, so as to accomplish the objects for which the Institution has been established.

And first of all, as to the prevention of Accidents in Mines.

I think it is a source of justifiable gratification to contemplate; the readiness, almost without an exception, with which the Members of the profession have come forward in obedience to the wishes of those benevolent Noblemen and Gentlemen, who thought that the establishment of such an Institution as this, might contribute towards averting those dreadful accidents; and the anxiety which they have evinced in modelling the Institution, so as to accomplish the object in view.

No set of persons certainly can have more powerful motives to associate together for such a purpose than Mining Engineers; feelings of humanity towards those hardy and adventurous class of workmen, who are immured in our mines, and who suffer by such calamities—the heart-rending scenes which those in charge of such works are compelled to witness on such melancholy occasions—and the distressing bereavements which are continually brought to their very doors, appeal with irresistible force to them above all others, to associate together, if by such an association they can in any degree aid in preventing the recurrence of such fearful visitations.

If these considerations, and no others, operated towards the establishment of such an Institution, sufficiently powerful motives to urge us on, exist; and if we succeed—if our efforts, in however slight a degree, contribute to confer additional safety to our mines—the reward—the approbation of our own consciences, that we may have been the cause of even saving the life of one of our fellow creatures—must be a sufficient inducement to force upon us the utmost exertions of which we are capable, in contributing our mite towards the success of such an Institution.

It has been stated, that we are not the proper persons to unite together for such a purpose.—That we are interested persons, and that the proper persons for such an association, are persons entirely unconnected with the Coal Owners, or with the Managers of Mines; I beg most decidedly, but most respectfully, to doubt the soundness of such a doctrine.—The motives of any gentlemen, of whatever class they may be,

or whatever may be their pursuits in life, who unite together, or in any way contribute towards the prevention of those accidents, cannot be too highly appreciated; the Miners—the Coal Owners—and every one engaged in mining, owe them a deep debt of gratitude for any efforts they may make.

It is from those very feelings, emanating from persons themselves daily exposed in the mines, with those who are liable to suffer, being also individually subjected in the exercises of their duties, to the effects of such accidents—witnessing the heart-rending scenes occasioned by such accidents—and from being supposed to be the only persons, through whose assistance any preventive measures can properly be carried out, that we have deemed it incumbent upon us, and that we consider ourselves a proper class of persons to unite together and at least make the attempt, to endeavour to accomplish the desired object.

At the same time I feel assured that I speak the sentiments of every member of the profession, when I say, that we do not for one moment entertain the idea, that the establishment of this Institution should in the least degree render it unnecessary, or that we should interfere in any way whatever with the establishment of any other Institution, for the prevention of accidents in Mines; and particularly with the one proposed to be established in London. On the contrary, every member of the Institute, I am sure, either individually, or in connection with the Institution, would be most happy to co-operate with, assist, or in any way aid the efforts of any other Institution or Society, having for its object, the prevention of accidents in mines: and that it will be one of the leading objects of this Institution, to consider, afford a careful and impartial trial, or carry into effect any suggestion, plan, or measure submitted to them, having for its object, the prevention of those accidents.

I have thought it necessary to trouble you with those remarks, in consequence of allegations having been made, that the object of the establishment of this Society was to stifle enquiry—to interpose difficulties in the establishment of other Societies—or to create obstacles to the introduction or suggestions of measures recommended by such Societies, towards the prevention of accidents in mines. Whereas, our wish is, and it is our desire, and it should be clearly and distinctly understood, that our object is quite the reverse:—that it is our wish to aid, assist, and carry out the views of such associations—to carefully consider any plan which may be submitted to us—bring our united practical know-

ledge to bear upon such consideration; and if the measure, or plan, is at all feasible, or exhibits reasonable prospect of being beneficial, or to accomplish the object for which it is proposed, to do our utmost in giving it a fair and impartial trial.

And here it may not be irrelevant to those considerations or without its use in elucidating the objects we have in view, to glance at what has of late years been done towards the prevention of Accidents in Mines, induced by the frequency and serious extent of those Accidents; and to see how far these enquiries have contributed to arrest the fearful visitations.

In the year 1835, a Committee of the House of Commons was appointed, of which Mr. Joseph Pease was Chairman, a Gentleman from being himself an extensive Coal Owner, being in daily communication with his Mines, and being by his talents, application, and sound practical knowledge, every way suitable for that office. The result of the labours of that Committee, which sat hearing Evidence over a period of 19 days, and produced a Blue book of 360 pages, did not lead to any prominent alleviation of such accidents. They reported "In conclusion your Committee regret that the results of this enquiry have not enabled them to lay before the House any particular plan, by which the Accidents in question may be avoided with certainty, and in consequence no decisive recommendations are offered,—They anticipate great advantages to the public and to humanity, from the circulation of the Valuable Evidence they have collected.—They feel assured that Science will avail itself of the information, if not for the first time obtained, yet now prominently exhibited: and that the parties for whose more immediate advantage, the British Parliament undertook the enquiry, will not hesitate to place a generous construction on the motives and intentions of the Legislature."

In the year 1839, (resulting from a serious explosion of Fire Damp at St. Hilda Colliery, near South Shields, by which 50 people were killed,) a Committee was appointed of South Shields Gentlemen, of which Mr. Mather was Secretary, and which sat occasionally for 3 years.—The result of that Committee was a Report of very great value, published in 1843. It has also been republished, as an appendix to the Report of a Committee of the House of Commons, of this year.

The conclusions to which this Committee arrived were rather numerous.—With regard to SAFETY LAMPS, they concluded that "no

mere Safety Lamp, however ingenious in its construction, is able to secure fiery Mines from explosions; and that a reliance upon it is a fatal error, conducive to those dreadful calamities, which it is intended to prevent."

With regard to VENTILATION, "that considering its power, safety, and economy, facility of execution and command, Ventilation by High-pressure Steam is peculiarly fitted for the present condition of Mines, and adapted for them in every stage of their operations.—That it appears one of the most important and valuable suggestions, and if fully and properly applied, preferable as far as relates to its effects on the safety and healthiness of the mine to any invention of modern date."—The committee recommended the use of Scientific Instruments, some regulation of Infant Labour, Registry of Plans and Sections, Scientific Education of Officers of Mines, and Government Inspection and Jurisdiction.

In 1845, Sir Henry de la Beche, and Dr. Lyon Playfair, were appointed by government to institute an enquiry into the causes of Accidents in Coal Mines, particularly as regarded the noxious and inflammable Gases, the escape of Gas into Mines, and of obviating danger therefrom by proper Ventilation.—The Labours of these Gentlemen were published in 1847, and the general result appears to have been the recommendation of the appointment of Government Inspectors; and to compel the use of Safety Lamps in all fiery collieries.

In 1849, in consequence of the continuance of those accidents, a Committee of the Lords was appointed, of which Lord Wharncliffe was Chairman, a nobleman every way qualified for such a task. This committee sat receiving evidence 18 days, and produced a Blue Book of 615 Pages.—No Legislative measure was recommended to Parliament by this committee.—They contented themselves with reporting the Evidence, with a commentary upon it in their report, directing attention to various parts of the evidence, especially as regarded the appointment of Inspectors, to improvements in Safety Lamps, and of Ventilation generally; and directed particular attention to the precise action and power of the Steam Jet as a Ventilating Agent, compared with that of the ordinary Furnace, hitherto in use.

During the Session in which this Committee sat, an appointment was made by the Government of Professor Phillips and Mr Blackwell, to investigate and Report on the Ventilation of Mines.—These two Gentlemen made separate Reports;—the former of the Mines in

Northumberland and Durham, Derbyshire and Yorkshire; the latter in Lancashire, Staffordshire, Shropshire, and South Wales, &c.

Those Gentlemen produced a valuable mass of Evidence and Investigation, giving the facts as regarded the system and amount of Ventilation at the different Collieries, and in the different Districts.—The conclusion they arrived at may be shortly stated, by saying that they considered superior practical and scientific Knowledge was required in some of the Districts.—"superior skill, and unsleeping vigilance in the overlooker;"—which they thought would be promoted by the establishment of provincial Mining Schools, and by a systematic Inspection under the authority of Government.

In 1851, Government Inspectors were appointed; unfortunately however accidents still occurred, and in this Year a Committee of the House of Commons was appointed, of which Mr Cayley was chairman.—This committee sat receiving evidence 5 days and published a report of 247 Pages, (including the reprint of the Report of the South Shields Committee.)—This Committee has made various suggestions, some of them of a most startling nature, both as regards the practicability of their adoption, and their utility in accomplishing the objects for which they are recommended: and certainly great doubts exist as to the propriety, as well as the efficiency of several of their suggestions, as regards the Ventilation of the Mines. One of the opinions they express is—"Your Committee however are unanimously of opinion that the primary object should be to prevent the explosions themselves: and that if human means (as far as known) can avail to prevent them it is by the Steam Jet system as applied by Mr. Forster; although even in such case it might be prudent in a mine especially fiery to add an inexpensive Steam Jet apparatus at the top of the downcast, as a means in reserve in case of explosion from neglect or otherwise; and your Committee are unanimously of opinion that the Steam Jet is the most powerful, and at the same time least expensive method for the Ventilation of Mines."

Looking at the Evidence produced before those Committees at the various periods—the information elicited by the labors of the scientific Gentlemen employed to report upon the subject—the conclusions, and recommendations which those Committees and Gentlemen have from time to time arrived at or made; and more especially looking at the conclusions and recommendations which the Committee

of this year has made to the Legislature, I need scarcely say how incumbent it is upon the proprietors and managers of Mines to carefully, minutely, and impartially study and consider, such a mass of Evidence, and the important conclusions to which those Gentlemen have arrived at, or measures which they have recommended.

And here I may again perhaps be permitted to state that the Institution which we are now engaged in establishing, is probably the most proper tribunal to enter upon such an investigation.

It has always been felt that individual Collieries, or individual Coal Owners, were not able or capable of undertaking such extensive experiments as would be required to test some of the suggestions made, or schemes proposed by those Committees, or by Scientific Gentlemen or others; and thus on the principle that what was every body's business was nobody's business—these voluminous Reports, those various, and in some instances probably useful or valuable suggestions have lain dormant—or have been placed upon the shelves of the Colliery Offices without notice or attention.

Now however we have no such excuse open to us, being associated together for the express purpose and object of probing, and investigating every thing connected with the subject of Mining; however crude, inapplicable, or even however ridiculous the proposition or plan may be, it is just as incumbent upon us to give it a fair and impartial investigation as if were the most perfect or valuable suggestion.

Acting as a body, every plan brought before us will have at least a careful and impartial investigation, and if we unitedly find that any subject requires practical elucidation, or if in order to enable us to arrive at a satisfactory conclusion, it is necessary that any plan or suggestion should become the subject of experiment, I feel assured we shall be readily met by our employers, to place their pits at our disposal, and enable us to test by practical experiment or experience, any plan, mode, or suggestion, which may be offered to our notice on so important a subject,—provided we are unitedly of opinion that such experiments or trials can in any way conduce to lessen the number of accidents in Mines, or tend to advance the Science and economy of mining.

Apart however from the suggestions resulting from the labours of these Committees, and from the investigations of professors and others,

we have the subject generally of Ventilating and Lighting of Mines open to us, and calling upon us for investigation and discussion; and looking at the variety, importance, and intricacy of these subjects, there can be no apprehension that the Institute will be at a loss for materials to discuss, and looking also at the anxiety evinced by the Members in the outset, no reasonable assumption can exist that any part of the subject will not undergo the requisite investigation and consideration.

Within the last 40 years to my knowledge, and to the experience of some of my colleagues, mighty and important changes, and improvements have been made in the Ventilation of Collieries —It is true we still retain the Furnace as a Means of Ventilation—some say as an old friend—some from predjudice—still we retain it. We have had as a substitution during that period innumerable plans, and suggestions, few of whom have stood the test of time and experience,—we have had the application of Machinery suggested in almost every variety of form to produce a current of air through the Mine by pumping the air out of the Upcast Shaft; and we have had some to force the air down. All these appear to have given way to two modes by Machinery now in use, one by Mr. Brunton, acting by centrifugal force, in the compartments of a wheel of large diameter; and one by Mr. Struve of a direct fan action. Then we have the Steam Jet, (strongly recommended by the Committee of this year,) originally proposed by Mr. Goldsmith Gurney to the Committee of the House of Commons of 1835, and more particularly described and illustrated in the Report of the South Shields Committee in 1840, but which was not brought into operation until 1848.

These different modes of ventilation, ought to form the earliest subjects of our investigations—they have been brought before us in a shape which makes it incumbent upon us to proceed to their investigation with the utmost care and impartiality, and without loss of time; but still in such a way as fully to test their relative capabilities, and their applicability in all or any of the cases in mining. With the resources within your reach, or which I feel confident will be placed within your reach, it is incumbent upon you to set the question at rest in a practical point of view.

Besides the enquiry as to which of the various modes of ventilating exhibits the greatest power of abstracting the air up or down the Shaft—there is a great deal to investigate in the Shafts themselves. The effects on Ventilation with Shafts of greater or less diameter—the com-

parative effect with Shafts of different depths, and other modifications, all will, or ought to occupy your attention, and perhaps all the requisite data can only be obtained by an accumulation of facts such as will now be afforded you by this Institution.

When however we have investigated and arrived at the conclusion, as to which plan produces the greatest current of air down the Shaft, we have only arrived at the threshold of Ventilation. One of the parts of the subject which has undergone the least investigation, and which is decidedly the most important, is the principles, or application of the conveyance of air through the Working of the Colliery;—or from its entry into, to its exit out of the mine. We have found that passing one single current of air through the working of a mine, from its entry to its exit, is attended with considerable resistance, such as to render it impracticable in a very long current to produce other than a very moderate velocity, or in Mining language a small current of air. And experience has shown that, by what is called splitting the air, or by dividing it into a greater number of currents, with corresponding shorter runs, a greater aggregate quantity of air is obtained, or a greater quantity than would be measured by the number of divisions into the quantity obtained by a single current. That in fact if a single current of air is divided into four currents, you obtain in each current, a much greater quantity of air than one-fourth of the original quantity in the single current; but we have not, to my knowledge, arrived at any tangible principle or rule by which this is regulated.

The conveyance of the air through all the workings of a Colliery is even therefore in 1852, a subject requiring serious investigation. And probably it has been the very want of such an Institution as this, that such and other investigations of a like nature have not been made before, as such investigations could not be gone into with complete and accurate effect, except by bringing together a variety of instances and facts, attainable only by an association, when each member can contribute his quota of materials towards a general result.

Then, I think that we may safely say, that much yet may be learned as to the emission or discharge of the different gases found in the Mines, which may be useful in a practical point of view, both with regard to the guarding against the sudden discharges of gases, as well as how to deal with them when evolved.

We come now to the lighting of the Mines; and it will be found that great part of the labours of the parliamentary Committees and others employed to investigate the subject of accidents in Mines, has been taken up with enquiries as to the relative merits and safety of the different Lamps.

It may be necessary to ask you to revert to the period before the invention of any Safety Lamps at all—when the only lights used were naked candles; and in parts of the mine which were explosive, Steel Mills, or flint and steel. The latter gave, as may be supposed, a very imperfect and uncertain light, dependent upon the dexterity of the operator or mill-player, producing or not, a continuous succession of sparks. The Steel Mills were consequently only used in exploring the old workings or waste.

All the Mines may then be said to have been worked with candles until the year 1815, when the Safety Lamps were introduced.

We find that since the invention of the Safety Lamp in 1815, there have been more Accidents than when the Mines were entirely worked with candles. This would at first sight appear paradoxical, but the reason is obvious. Coal is worked now which could not then be worked. Mines which yielded large quantities of gas could only be partially worked in the whole mine, and in such mines pillar-working could not be attempted; hence a large proportion of the Coal in the District was either unworkable or unworked. Since the use of Safety Lamps these mines have been worked, and the pillars which were then left, are now in the course of working with Safety Lamps. It is therefore in those mines and in the pillar-working that the use of the Safety Lamps are rendered necessary; and it is in some of those mines,—in pillar-working,—and in the vicinity of goaves that it is impossible to keep the workings free from gas; hence the liability to explosions, and hence also if an accident does occur, the reason why it is much more disastrous, than when the mine was worked with candles, and when such of the mine only was worked as could be freed from the presence of inflammable gas, or reduced below the inflammable point. The number of accidents or deaths from explosions in the counties of Northumberland and Durham we find for 60 years previous to 1815, or when Candles were used, was 734; while in 30 years afterwards the number was 968, with the use of the Safety Lamp; and we have the more appalling fact, that since November, 1850, (the commencement of the Act for the appointment

of Government Inspectors,) the number of deaths by explosions has been at the rate of 250 per annum. These results urge upon us with awful force, the question of whether any thing can be done, under such a system of working the mines, as would to any degree avert such dreadful consequences.

The subject of Safety Lamps will therefore no doubt form the subject of your early and anxious investigation, and no part of the subject will require more serious or careful attention. It is now I may say almost impossible to conduct the mining operations of this District without having some Collieries or parts of Collieries subject to be overloaded with inflammable air at times, and it is therefore of the utmost importance that those parts of the mine should be approached with a perfectly safe Lamp, if such a desideratum is attainable.

The opinion given before the Committee of the Commons, which has just issued their Report, of the insecurity of the Davy Lamp, and the fact that thousands of those Lamps are daily used in an inflammable atmosphere; renders this an inquiry of vital importance to the safety of the Miner, and the security of the property of the Coal Owner; and I feel therefore assured that you will approach such enquiry with that anxiety and interest which the importance of the subject demands.

I think I have now exhausted what I have to say on the first part of the duties of this Institution, and I fear I have exhausted your patience also. I must however beg to say a few words on the second part of the object of this Institution, viz,—that part which is more purely of a scientific, practical, and professional character, and which may be generally summed up in that part of mining which applies to the theory and practice of the Winning and Working of Collieries.

In the Winning of Collieries, the first process is that of Boring. I feel assured that it would be a very useful work in the archives of our proposed Institution, if we possessed detailed plans of the different Boring Instruments used here and on the Continent.

In the Borings for Coal, and in the Borings for Artesian Wells, there are a great variety of Boring Apparatus; I trust ere long we shall have from some of the Members of our body a paper on the subject, accompanied with the requisite Plans and Drawings.

The next subject which presents itself is Sinking Pits; and here there is a vast store of knowledge scattered about in the Trade, laying in unprofitable obscurity in the drawers, and in the archives of the profession. I trust that their anxiety to support the character and utility of the Institution, will induce them to bring those documents to day-light, and that they will impart their experience to their brethren. There is nothing so important, nothing so useful, when unsuccessful, than that we should have communicated to us the causes of failure;—and it is equally important and useful, to have the experience of successful efforts, in overcoming dangerous and difficult undertakings.

This District more than any other, yields instances of the most expensive and difficult sinkings for Coal. It will be of the greatest value to have records of them, and detailed plans, and correct descriptions of the works of extensive Sinkings. We have had only recently, two very important and extensive Sinkings, of great depth, and in one of the instances, of extraordinary difficulties. It would be of great utility to the rising members of the profession, and probably to some of more experience, if we could have placed in our archives correct records of the means practised to overcome such difficulties.

The two instances to which I allude are the Murton and Seaton Winnings, within two miles of each other—one an instance of the largest quantity of water probably ever overcome at so great a depth, I believe about 8000 Gallons a minute, or upwards, from a depth of 70 or 80 fathoms. The other, within that short distance, a case of having passed through precisely the same strata or measures without having ever met with, at one time, more than 500 Gallons per minute. I trust ere long we shall see amongst our papers and plans, the experience, and all the details of those two important undertakings Having myself had charge of one of them, I undertake to furnish the Institution with the details of the Seaton Winning; and I have no doubt my friend Mr. Potter will be equally ready to furnish an account of the more difficult and extensive one of Murton.

Besides these cases there have been many others, from a record of which, much information and instruction may be gained. Then

we have the consideration of the different kinds of Tubbing suitable for all the variety of sinkings. Something also, of the preservation of that Tubbing exposed to the smoke in upcast Shafts, or to other destructive gases or water—all important questions for discussion and elucidation.

The different descriptions of engines, machines, machinery, pumps, and all the variety of apparatus for raising water when it does find its way into the Shafts, all form subjects likewise on which the Institution might be profitably occupied for a long period of time; and on which much valuable information and instruction, derived from records of what has been done, and from the experience of those gentlemen through whose supervision and direction, such works have passed, or by whom they have been executed, may be obtained. And allow me to say, that no doubt whatever can exist, that the information—the dissemination of the knowledge and experience of those gentlemen who have executed such works—brought out in the discussion of this Institution, will be duly appreciated by those to whom such information must be invaluable, viz.,—the young members of the Association.

And, I trust I may also be allowed to add, that it is equally clear and certain, that such information must be of the utmost value to those to whom we look for support, viz.,—our employers, as enabling us to bring to bear upon the execution of such works as we may be intrusted with in future, the accumulation of all the experience of the Trade, elicited by the papers presented, and from the discussions which will arise thereupon.

Next comes, the working of the Coal and the machinery connected therewith; and here a wide field is open to us. When we look back to no very distant period, little beyond the last generation, we find that a very large portion of the Coal now in working was utterly unapproachable. The machinery then in use was not capable of combating the difficulties attendant upon its increased depth and other circumstances. What has since been done? What revolutions have we not passed through, in all the concomitants of mining and locomotion? The pumping of water, and drawing of coals by water-wheels will be in the recollection of some of our members, and it is only very recently that one of the old engines with the cylinder upon the hay-stack boiler, the steam passing between them through a slide-

valve only, has given way to the modern improved engine. And we have had within our own times, the invention and introduction of the locomotive engine which now performs such wonders.

What has been the condition of Mining operations through all these variety of changes and improvements? Coal once considered unapproachable, is now worked and brought to the surface with as much ease as if it were only a few yards deep. The range of the Workings of some of the large Collieries now extends over a space which required several pits some years ago. I took the opportunity of stating on a recent occasion that in the Hetton Colliery there were 40 miles of single Railway underground. Improved modes of working the Coal and conveying it underground have also been adopted, or have become necessary. All these however implies a constant and continual succession of improvements, alterations, and adoption of new systems, or modes of working the Mines, and in the conveyance and raising of Coals, induced by the progress made in the improvement of Machinery and advancement of Science, and rendered more imperatively necessary to meet the increased cost and expence of working the Coal. And do not let us entertain the idea that we have arrived at perfection—we are yet in a state of progression—in a state of transition, and improvement;—and in the ratio of what has been done, so much the more is required of us. Our predecessors have succeeded in raising the standard of intelligence in the art of Mining, and in the use of Machinery much beyond that of former times; what they have done in raising the standard up to its existing scale, let us emulate, improve, and raise it further, so as to keep pace with the increasing wants, intelligence, and requirements of the age.

Bearing all these in mind what does it suggest to us?—First, to inform ourselves of all that has been done; and when all this is made patent to us, to unite together in heart and mind, and endeavour by our combined efforts to keep pace with, or if possible, to outstrip our predecessors in the field. And, allow me to say, if we accomplish as much in our time, as our predecessors have done, within the last 40 years, we shall be no mean contributors to Science and the Arts. Let us at least make the attempt. There is no finality in Science. We must progress, and availing ourselves of the opportunity which the establishment of this Institution will, I trust, afford us, let us put our shoulders to the wheel, and prove ourselves no degenerators from our predecessors.

Acting up to those principles and examples, we ought to set ourselves to work and fill our shelves with plans and information of all the labours of our predecessors; from this we shall no doubt acquire a great deal useful to us as a guide in our subsequent investigations. The different modes of working coal, and the applicability of all those different modes of working to the various descriptions of Coal, or under different circumstances, all require elucidation. We have recently had introduced the long-wall mode of working, a mode of working which has been practised in other districts for years back. It has been often introduced into this district, and as often rejected, as inapplicable to the Seams of Coal in this locality;—it has however now obtained such an ascendancy as to require the serious attention of all concerned in Mining, how far its use can be extended, and under what circumstances it can be adopted, or under what modifications it ought to be practised. Need I say that this is a subject peculiarly appropriate for discussion in our Institution. And when we consider the ramifications into which this subject will spread, we have no cause to apprehend a want of matter even under this branch of knowledge to occupy our labours.

This is, it may be stated, the subject above all others in which the proprietor of the Coal is most deeply interested. Any measure which has the effect of producing the largest possible quantity of Coal out of a given area of royalty, and that in the best possible condition, is of the greatest importance to the Lessor. Let me then venture to hope that, in the proportion in which he is interested, will he contribute his quota towards the support of the Institution.

Having some consideration for your patience I shall leave the subject of working the Coal, however important it is, and shall ask you to allow me to say a few words on the conveyance of the Coals both underground, and on the surface. Considering that almost every day the distance is increasing, from which the Coals have to be conveyed from where excavated to the Shaft, it becomes of the greatest importance that the best and most economical modes of conveyance should be adopted, and therefore latterly the attention of the Viewer has been more particularly directed to the application of Engine-power under-ground than heretofore.

Consider therefore that the subject is yet in its infancy—that there yet remains much to be done—that the application generally is scarcely yet commenced, much may therefore be learnt by a free and practical discussion on the details of such applications—the experience of those who have used such Machinery—the result as regards cost of Erection, cost of Working, and the useful effect produced,—or practical performance of those Machines, all require to be investigated and discussed, and which would be extremely useful to the profession.

The conveyance of Coals and other minerals above-ground is not a less important subject of enquiry.

The different description of carriages used both below and above-ground should also undergo investigation; and their relative amount of friction, wear and tear, &c.

The shipment of Coals, the saving of breakage of the Coals, their conveyance and delivery to the consumer, have all become of late, subjects of some importance to the Coal Owners. It will not be irrelevant therefore to the object of the Institution that these should become subjects of investigation and discussion. And even the question of the comparative cost, utility, and applicability of the Screw Colliers in the conveyance of Coals, might be a subject of some interest in the proceedings of this Society.

I have I fear, at too extended a length, occupied your attention with the consideration of those portions of the constitution of our Society which relates to Accidents in Mines; and to the practical or operative part of Mining. We must not however neglect a most important branch, indeed the mainspring of the Society; that of the advancement of the Science of Mining, or the cultivation of those branches of science which more particularly appertain to our profession. The study of Geology and all its concomitant branches of Science, Mineralogy, Chemistry, Mechanical Philosophy, Pneumatics, and Mechanics, are all subjects which would occupy the time and attention of all the individual members of the Institution, and the meetings likewise of the Institute collectively, very usefully and profitably.

Papers upon any of these subjects would be extremely acceptable, and the discussion which might arise out of them, would, I have no doubt, be very instructive. I have already, on a recent occasion, in an Inaugural

Address on the establishment of a School of Mines, ventured to point out, that all these Sciences ought to enter into the education of a Mining Engineer. I feel assured that their investigation and discussion in after-life, must be equally instructive and useful in his profession.

Without therefore entering into detail on this part of the subject, it must be apparent to all that there is in those branches of Science, ample matter for a large portion of the time of the Institution. I would beg to refer to the work above alluded to for any further explanation on this head, though I have no doubt each individual Member is quite as deeply impressed as I am of the importance of the study, and of the knowledge of those branches of Science to a Mining Engineer.

A record of the Mining operations of this County has long been felt as a great and important desideratum, so much so as to cause it to become the subject of Parliamentary investigation. Let us hope that the establishment of this Institution may present an opportunity, or an inducement for the production of a record of Mining operations of this District. I am aware the obstacle has been the supposed exposure of private property, and the apprehension that such exposure might be injurious to the interests of those in possession of such documents. There may possibly be much predjudice in this. There are however a very great many cases to which such an objection could not possibly apply, and the production of such Plans and papers being of course voluntary, and in all probability through the hands of the professional adviser of the person possessing them, no harm, but on the contrary in my opinion, a great deal of good might ensue by an attempt to combine a local record of the Mining operations of this District with this Institution.

I need only instance one case, where no real objection can possibly exist, and where the deposit of such plans would be very valuable. The High Main Seam, (from whence up to a comparatively recent period all the Wallsend household Coals were produced,) is in the course of being entirely and irrecoverably filled or drowned up with water, on the South side of the Great Dyke to the level of the Tyne. It will shortly be one of the things that hath been. Surely there can be no objection to the production and deposit of the plans or copies of the plans of such a Seam in so extensive and important a District. The opportunity of doing so is now within our reach. But if it is not now done, time will scatter the materials into so many hands and places, that the opportunity may be lost.

It is to be hoped likewise that a Collection of the Borings, Specimens of the Strata generally, Specimens of the different Beds of Coal, and of the Minerals produced in the District, will be contributed, or obtained. We shall also, to render the Institution more efficient, and to enable us to carry its objects into full and useful effect, require Models to illustrate the different subjects within the extensive range of our duties and researches. It would be necessary also to have a Library to refer to, on all the subjects within the range of Mining, Engineering, and the different branches of Science which we shall have to cultivate. And lastly, we shall require suitable rooms to meet in, for our discussions, and for the deposit of our Models, Plans, Books, and Papers. And may I venture to hope that our funds may enable us to give rewards, or medals, or in some substantial mode to mark the approbation of the Institution for papers of merit, experiments made to promote the objects of the Society, or for important communications to the Institution, which may tend to lessen the number of accidents, or promote the economy, or efficiency of Mining.

In conclusion, I have endeavoured so far as I have been able, and within the limits of an Address, to point out to you a faint outline of the constitution of this Society—its objects, and the important duties which it will be expected to fulfil. I need scarcely add how important they are, not only to the literary and professional character of the Members of the Society, but to the extensive and important interests comprised within the scope of its labours. We have not confined ourselves to Members of the profession, or have made it purely of a Literary or Scientific Character. We have extended the sphere of our labours to all those studies and researches of an economical, practical, and useful character, in all the ramifications into which they are susceptible, and which can by possibilty bear upon the safety, success, and prosperity of the staple commodity of the District.

We have opened our doors to the admission, as I have previously stated, and as our Title points out, to all persons "interested in the prevention of Accidents in Mines, and in the advancement of Mining Science generally," and we therefore seek for support from all those persons.

But besides those Gentlemen who are interested from feelings of humanity, in the prevention of accidents, we rely for support from those Noblemen and Gentlemen who are, in addition to those feelings, personally interested in the Mining operations of this District. We have amongst them, Learned Bodies of great wealth and importance,—

Corporations, Noblemen, and Gentlemen of the first rank and respectability in the kingdom. We have advisedly abstained from soliciting Patrons, when there are so many who would do honour to the Institution, we have thought it advisable that such support should be voluntary, when the object of the Society is pointed out to them. And we trust that such support will flow upon us, in proportion as the importance and usefulness of such an Institution is weighed and considered by them. It would however be misleading those Learned Bodies, those Noblemen and Gentlemen, and the Public generally, if we were to hold out expectations that the Institution could be completely successful, or that we could accomplish what it must be apparent to all would be extremely desirable, without the patronage and support of those most materially interested in the success of the Institution—the Lessors and Lessees of the Coal Mines of this District. Without the requisite funds to provide us with tools, the edifice cannot be reared, or become useful, or accomplish the objects expected from it.

Allow me last of all to state, that in the proportion in which we are supported,—in the proportion in which the requisite implements are put into our hands, or placed within our reach;—in a like proportion ought our exertions to be increased, to accomplish, so far as our abilities, assiduity, and attention, will enable us to accomplish, the objects in view by the establishment of this Institution. And, that we may make a full and adequate return for the confidence placed in us, and for the support which we may receive, let us, as I have previously stated, each and every of us consider and act as if we considered ourselves individually responsible for the success of the Institution, and I have no doubt that our efforts will be successful.

NICHOLAS WOOD.

W. AINSLEY, PRINTER, DURHAM.

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

MONTHLY MEETING, FRIDAY, OCT. 1ST., 1852, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY,

ERRATA.

For *distressed*, page 4, line 1, read, *district*.
For *two*, page 12, line 18, read *three*.
After *diameter*, line 20, page 12, read, *one by Mr. Struve, of a direct pumping action, and one by Mr. Naysmith, of a fan-blast*, and omit the words after *diameter* to *Then*.

James R. Longridge, Esq. then read a paper "on the Action of a Jet of Steam, as a Motive Power for the purposes of Ventilation;" after which the Meeting was adjourned until Friday, 5th November.

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

MONTHLY MEETING, FRIDAY, OCT. 1st., 1852, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE.

Nicholas Wood, Esq., President of the Institute, in the Chair.

The minutes of the last General Meeting and of the Council Meetings having been read.

Messrs. Matthew Liddell, Joseph Davidson, Ralph Dixon, and William Coulson, were elected Members of the Institution.

James A. Longridge, Esq. then read a paper "on the Action of a Jet of Steam, as a Motive Power for the purposes of Ventilation;" after which the Meeting was adjourned until Friday, 5th November.

ON THE

ACTION OF A JET OF STEAM

AS

A MOTIVE POWER

FOR

PURPOSES OF VENTILATION.

READ BEFORE THE

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS,

&c.,

ON FRIDAY, 1st OCTOBER, 1852.

BY JAMES A. LONGRIDGE.

Newcastle-upon-Tyne:
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1852.

THE

STEAM JET AS A MOTIVE POWER

FOR THE PURPOSES OF VENTILATION.

The subject which I have to-day the honour of bringing under your notice is one of deep interest and importance, and as such merits our gravest consideration. The application of a Jet of Steam as a motive power for purposes of ventilation has given rise to considerable discussion, and the great claims advanced by certain parties on its behalf, sanctioned and corroborated as they have lately been by the verdict of a Parliamentary Committee, and its immense value in Mining operations, if these claims be well founded, demand a close investigation on our parts. We are met here this day in furtherance of a great object, the Prevention of Accidents in Mines, and the Promotion of Mining Science and Art. We have a high and solemn duty to perform, and in its inception let us not forget that in this, as in all other undertakings, if we would be successful, if we would establish for our proceedings a character beyond the discussions of a mere debating society, if we hope to benefit our fellow-creatures, we must lay aside all prejudice, and all the harness of habit, and, influenced by the love of truth alone, calmly and fairly examine the pretensions of the advocates and the objections of the opponents of the system to which our attention is at this moment so loudly called.

It should be at all times an object of interest to men whose pursuits are of the nature of those which occupy the gentlemen I am addressing, to investigate any new phenomena, or any new application of well-known agencies, and how much the more so when the direct bearing of the question is upon so momentous a subject as the lives and property of their fellow-men, those with whom they are daily and hourly in contact; but to do this in a manner satisfactory to an intelligent mind, it is not sufficient to listen to a bare recital of unconnected facts, or isolated experiments upon however large a scale; instinctively we crave after a more intimate knowledge of the principles and laws of action of the agent with which we deal, and

until we can unravel the intricacies incidental to the phenomenon, and lay bare the secret laws, the mind can never rest.

Actuated, then, by this feeling, I thought that it might be acceptable to the Society to have laid before it the results of certain experiments which have been made with reference, not so immediately to the application, as to the principles and laws of action of a Jet of Steam as communicating motion to air for the purpose of Ventilation. When I mentioned to the Council my intention of bringing the subject under the notice of the Institute, I hoped to have been able to do so in a much more complete manner than I can do to-day. I did not anticipate many difficulties and anomalies which I have met with, and which have rendered a multiplication of experiments necessary to an extent which I never contemplated, and their discussion a work of more time than I have been able to bestow. I must, therefore, crave your indulgence, and beg to defer to a future opportunity the production of the formula which I trust to establish as the embodiment of the laws of action of the Jet.

Up to a very late period I still hoped to have carried out my original intention, and much of this paper was written under that impression, therefore, if it appears to promise more than it performs, you will please to bear in mind what was the intention of the writer, and trust to his redeeming his promise at, I hope, no distant period. Deeply conscious of the imperfect state of this paper to do sufficient justice to the subject, and knowing that it is the intention of our President to lay before the Institute, at a future meeting, the results of his observations upon the Steam Jet as practically in operation, I trust that I shall not be thought presumptuous in thus calling your attention to the subject, with the knowledge of such intention on the part of one of his great experience. I shall have little or nothing to say of upcast or downcast shafts; of mighty streams of air, descending into the bowels of the earth, travelling there for miles, and again ascending to the realms of light and purity, bearing along with them the deadly gases, the miner's invisible but fearful foes: I shall describe to you a small and simple apparatus, constructed of wood and of tubes of tin, but I trust that the experiments made therewith will not only elucidate the principles upon which the operations of ventilation are based, but afford, also, to some extent, practical data whereby the Viewer may be guided in designing future works on any scale whatsoever.

The present may then be termed a theoretical investigation of the

subject, but let me not be misunderstood: a theoretical consideration of any question is too often regarded as a mere field for the exercise of abstract reasoning and mathematical ingenuity, but of little value to the practical man. But theory, it can never be too often repeated, is in no case at variance with practice. It is simply because the theory is not sufficiently perfected that the practice of theoretical men has sometimes failed.

It is because theory is still imperfect that its predictions are not unfrequently falsified; it is because all the accidents, as they are called in logic, are not seen and appreciated as such, because their interferences and their combined actions are overlooked, that the theoretical differs from the practical result. But this is no reason why the investigator should shut the eyes of his mind, and follow blindly and gropingly in the footsteps of his predecessors.

The human intellect is too active, too progressive in its sympathies to rest contented with the bare facts of former experience: it struggles onward, and rests not, and will not and cannot rest till the intricacies and combinations of phenomena are unwound, and the simple laws of nature, in all their extent of reach, and in all their unity, and at the same time their multiplicity of action, stand revealed in simple and satisfying grandeur.

Least of all, in this our day, should the theorist be taunted with the barrenness or the imperfections of his theory. Day by day his knowledge, his insight into the arcana of nature's laws increases, and day by day he gains a vantage ground over outward nature, not as has been well observed, by compelling her to work in despite of her laws, but by putting her into a position such, that by the operations of those laws alone, his purpose is accomplished.

I have already occupied your time too long to go further into this question, although I might, perhaps not without profit and interest, point to many wonders of construction and art which, but for the theorist, might never have existed; but I will only mention one, which, from its magnitude and novelty, may well claim the pre-eminence, even in these teeming days of wonders. It was not by following in the footsteps of his predecessors in the trodden tract of conventional practice that Mr. Robert Stephenson designed and successfully executed that magnificent work, the Menai Bridge. Here he had no previous practice to guide him, had he even been

disposed to trust to it. Impelled by the necessities imposed upon him, he struck out a new idea, and to give that idea reality, he called to his assistance men of profound theoretic knowledge. Step by step they patiently, and under the guidance of theory advanced, till from the model of the workshop, they evolved those properties which have proved their correctness by the stability and effectiveness of the vast structure itself.

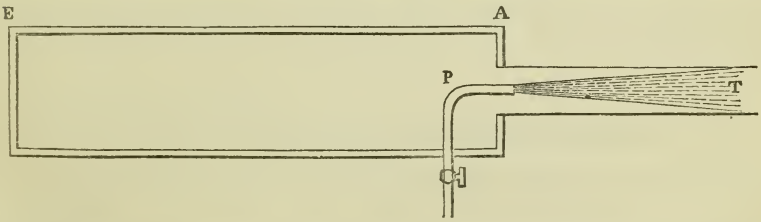
But reverting to the question before us. Before proceeding further, it may be well to correct a misapprehension which appears to exist in the minds of many, and in none more vividly than in that of the original proposer of the Steam Jet as a means of ventilation, with respect to the action of the Jet upon the surrounding air. The steam rushing out is conceived of as pushing before it the column of air. It is spoken of as an impulsive force, as a *vis a tergo*. For instance, Mr. Gurney, in his evidence before the Committee of the Lords, on the 22nd of June, 1849, when asked to describe the distinction between high and low pressure steam, in reference to this effect as a means of ventilation, says :—

"The one acts by impulse, or *vis a tergo*, the other by rarefaction : low pressure steam has no momentum of escapage, it escapes comparatively slowly into the air ; high pressure steam escapes with considerable force, and when high pressure steam is allowed to escape through certain sized openings, it drives a volume of air before it mechanically." Again, in in another place he says :—"High pressure steam, if placed at the bottom of an upcast shaft, has the property of conveying warmth to the column in the shaft, and also that of giving the more powerful action of *vis a tergo* or momentum, by proper arrangement, *driving if I may so express it, the whole column of air up the shaft before it.* The column of air in the shaft being thus driven out, a call is immediately made upon the galleries of the mine for a supply to take its place, so that, supposing we have a number of Jets, the high pressure Jets force the air in front of them and thus leave an exhaustion behind. It may be said to act doubly, first as a force pump in front producing compression, and second by drawing and causing exhaustion." Again, in the last blue book on the subject, the production of Mr. Cayley's committee of last session, we find, amongst what are therein termed "Definitions and Technical Explanations," a description of the mode of action of the Steam Jet, as follows :—

"The Steam Jet acts in a manner totally different (from the Furnace). It is a *mechanical* force applied to propel the air through the

shaft. When a Jet of high pressure steam is blown into an atmosphere at a state of rest, it produces a violent disturbance in that fluid. The particles of steam are in rapid motion, and since the first law of motion is that a body in motion continues to move for ever, or until stopped by something else, when stopped it communicates its force to the body stopping it. The force of the Steam Jet is expended in the air on which it *strikes* and through which it passes, and this force is applied to the air as fully as if it were applied to a piston in a steam engine."

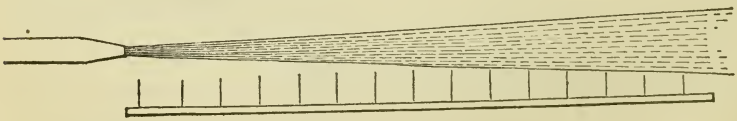
Here, as well as in Mr. Gurney's evidence, the steam is conceived to act somewhat in the manner of a piston driving the air before it, and leaving a vacuum behind. But it should be borne in mind that if the steam is a piston at all, it is a continuous and self-generating piston, and fills up with its own bulk the space it generates, so that, as far as the air in the mine is concerned, the *impulsive* force of the steam can have no effect upon it, because, being behind the piston, it cannot get past it so as to get in front to be subjected to impulsive action. A partial vacuum is indeed induced behind the Jet from a cause which I shall presently explain. The amount of this vacuum depends upon the tightness, if I may so speak, of the steam piston, *i.e.* upon the smallness of the ratio existing between the area of the shaft or funnel in which the jet acts, which may be called the blast pipe, and the area of the jet itself. If the blast pipe be nearly the same area as the jet, the result will be a high degree of rarefaction behind the jet, amounting, it may be, even to as much as 20 inches of mercury; but in this case it will be found that the dynamical effect as a pull upon the air behind is very insignificant. This is easily shown by a simple experiment. If we take a box of the form shown as follows, and apply



to one end of it A. a tube T., closing the other end E. by a slide or shutter, and if we apply to the end A. a jet of steam issuing into the tube T., and attach to any other part of the box a gauge of mercury, we shall find that if the area of the steam jet bears a large ratio to that of the tube T. a considerable amount of vacuum will be marked by the mercurial gauge in the box. The amount of this vacuum we shall afterwards find to

be a function of the pressure of the steam, and of the ratios of the areas of the jet and tube into which it acts. By increasing the pressure or the ratio of the area of the jet to that of the tube, we may obtain a high degree of exhaustion in the box, caused not by any impulsive force, but by a peculiar action of the steam to be hereafter explained. If, now all things remaining the same, the slide be opened, it will immediately be found that the vacuum is destroyed; but if we place an anemometer in the box, it may possibly be scarcely, if at all, effected by the action of the jet. The cause is manifest, viz., that the air contained in the box cannot get past the steam piston which, perpetually generating itself, fills up the whole tube. In order to give motion to the air behind, we must enlarge the tube so as to leave room for the air as well as the steam. By this, however, we diminish the vacuum, and, consequently, we arrive at this result, that the production of a vacuum is as it were the statical effect of the steam jet, whilst the ventilating power is the dynamical effect. The two are the inverse one of the other. It we increase the one we diminish the other, and *vice versa.* This seems to have been overlooked by some of the advocates of the Steam Jet, who, in claiming for it an almost unlimited power for ventilation, allege that exhaustion amounting to many inches of mercury has been produced, and *therefore* they argue any amount of ventilation may be obtained. That a great amount of ventilation may be obtained is not denied, but the expense of power is, as we shall soon see, enormous.

The ventilating power of the Steam Jet being then, not, as has been supposed, derived from impulsion, we must seek some other explanation. It will be found in the friction of the steam rushing through the air with great velocity and carrying it along with it. If we have a jet of steam, and parallel with it we place a long rod, to which are attached filaments



of silk or other light material, we shall find that upon bringing the rod within a certain distance of the jet, the filaments will start up at right angles to the rod, being drawn in by the rush of air towards the jet of steam. If now we attach longer filaments, we shall find them bending over in the direction of the jet, thus visibly showing the action of the jet upon the air.

A simple experiment, and one which probably has puzzled us all in our younger days, affords a very excellent demonstration of the attractive action of a jet of steam on air; and I mention it the more willingly because it is an instance of the attractive action overcoming the impulsive force, or, as Mr. Gurney would say, the *vis a tergo*.

To the end of a common quill, or any other short pipe, is attached a disc of a few inches diameter, another disc of the same size being provided upon blowing through the pipe and bringing the disc upon it within a short distance of the loose disc, the latter will be raised from the table, and will remain suspended so long as the current of air is sustained.

In this case, it is evident that the *vis a tergo* would blow the discs apart, but the direction of the air being changed, it spreads out in a thin sheet, and the circumjacent air rushing in towards it, keeps the lower disc suspended.

Having thus pointed out the mode of action of the jet, I proceed to investigate the laws which govern it, and the relations which exist between the force expended and the effect obtained. In order to compare the result with other modes of ventilation, it will be well to reduce the same to the effect of one cubic foot of water converted into steam, to which standard any other system is easily reducible. The following are the elements of the question, each of which may be considered as variable in its turn, whilst all the others remain constant :—

1st. Pressure of steam applied.
2nd. Water guage, or degree of rarefaction of the air drawn by the jet.
3rd. Area of jet.
4th. Area of pipe in which jet plays.
5th. Length of ditto.

To investigate the several effects of these variables, I constructed an apparatus of the following description :—A deal box, about four feet long, with a Byram's anemometer fitted into one end, and at the other a brass cylinder of about four inches diameter, with a steam pipe upon which to screw the jet's mouth piece. This steam pipe was about $\frac{3}{4}$ inch in diameter, and was furnished with a reservoir of considerable size, to which was attached the pressure gauge. A stop cock was placed between the reservoir and boiler so as to regulate the pressure of the steam passing out at the

jet at will. To the brass cylinder, within which the jet was fixed, were attached tin pipes of various diameters and lengths. These pipes we distinguish by the name of blast pipes. About the centre of the deal box two slides were placed, working in grooves in the sides of the box, and meeting at the middle, so as either entirely to close or to regulate the admission of air to the blast pipe. By these slides any required degree of drag upon the air may be obtained, they act as the friction of the air in the workings. Between these slides and the jet a water gauge was placed so as to measure the amount of "water gauge."

Thus the anemometer end of the box represented the down-cast shaft, the other end the up-cast, and the slides the resistance of the workings.*

Assuming, then, a certain degree of "water gauge," as what is required in the colliery (say $1\frac{1}{2}$ inches water) what we require to determine is—

1st. The most advantageous pressure at which to work the steam.

2nd. The best diameter of jet.

3rd. With a given jet, the best area and length of blast pipe.

And lastly, having ascertained the best area and length of blast pipe, we must then calculate the expenditure of steam from this jet, and so arrive at the effect of a cubic foot of water as steam.

This apparatus is almost identical with that used by Mr. Vivian, and differs from it only in the position of the anemometer, which, in his experiments was placed between the slides and the jet, and consequently registered the expanded air. An account of Mr. Vivian's experiments is contained in the blue book of the Lord's Committee of 1849.

The first series of experiments were made with a view to determine the most advantageous length of blast pipe. It is natural to suppose that a certain definite proportion should obtain between the diameter of the blast pipe and the length, in order to produce the full effect of the steam. The jet of steam issuing in the form of an inverted cone, and the motive power arising from the friction of that cone upon the circumjacent air, we are led to expect that the length of the blast pipe should not exceed the length of the cone of steam up to a point at which its diameter is equal to that of

* The writer has since had reason to alter the opinion here expressed, as will be seen by referring to a subsequent page.

the blast pipe. It is evident that so soon as the cone becomes equal in diameter to the blast pipe, the sides of the blast pipe, if prolonged, will then have not only no good but really a prejudicial effect, firstly, by the increased friction, and secondly, by preventing the further expansion of the cone which then fills the pipe like a piston, and prevents the free passage of the air. So soon, therefore, as the cone of steam touches, or nearly touches, the sides of the blast pipe, the function of the latter ceases. Experiments were made to determine the best ratio, and the result was measured by the exhausting power of a jet of steam in various blast pipes. In the first place the jet was $\frac{7}{100}$ of an inch in diameter, the blast pipes being $\frac{3}{4}$ inch, 1 inch, 2 inches, 3 inches, and 4 inches in diameter, the pressure of the steam being 20lbs. per square inch above the atmosphere. In each case the greatest exhaustive power was obtained when the length of the blast pipe was about eight times the diameter.

A jet of $\frac{35}{100}$ was then tried with the same blast pipes, the pressure of the steam being about 10lbs. per square inch above the atmosphere. Here again the greatest effect was obtained with the same ratio of eight times the diameter of the blast pipe. During the progress of the numerous experiments, made with different jets and pressures up to 75lbs. per square inch, a like result was obtained; it being found, however, that at very high pressures a somewhat increased proportion was less disadvantageous than when the pressures were low. Now it is evident that the exhaustive power is the best criterion whereby to determine this ratio, inasmuch as when it becomes a maximum it would be detrimental to its action as a motive power to increase the length of the blast pipe; any such increase of length being necessarily productive of increased resistance to the body of air put in motion. If, then, by increasing the length we diminish the exhaustive power, we may certainly, *a fortiori*, conclude that we diminish the motive effect But that we do so diminish the exhaustive power is well shown by the following experiment:—Diameter of Jet $\frac{35}{100}$ inch; diameter of blast pipe 1 inch, pressure of steam 10lbs.

Length of Blast Pipe in inches	101	77	57½	37	30	22⅛	17	10	3
Exhaustion, in inches of water..... ...	22¾	24½	25	27¼	27¼	28	28¼	30	25½

We may then assume that a length of blast pipe equal to about eight times the diameter is the most advantageous, and, as a deduction therefrom, it follows that as far as the *mechanical* action of the jet of steam

is concerned, its most advantageous position is at the top of the upcast. It is true that in an upcast shaft, when the jets are at the bottom, we do not isolate each jet in a blast pipe, but the effect would doubtless be more perfect could we do so, as we should thereby avoid eddies caused by the various jets of steam, which in practice, owing to the impossibility of obtaining parallelism amongst the jets we cannot avoid; but apart from any such eddies, the whole area of the upcast must be apportioned to the number of jets, so that each jet may have the proper fraction of the area and no more, and then the whole shaft may be considered as one vast blast pipe of great length beyond the jet, and, consequently, a certain loss of power results from the friction of the large volume of air and steam passing up it. A further disadvantage arises from the condensation of the steam which increases the specific gravity of the column in the upcast. How far this is counterbalanced by the gain due to the rarefaction, is a question which we will discuss hereafter, our business at present being solely with the mechanical action of the steam.

The next step in our investigation is to examine the effect of varying the diameter of the blast pipe. This part of the subject is of more difficulty. The exhaustive power alone is no longer our criterion. As we before stated, we have now the dynamical effect to consider, or rather a combination of the statical with the dynamical, inasmuch as we have a body of air to move, and a degree of exhaustion representing the drag of the air, to sustain. In practice the amount of this depends greatly upon the area of the air passages and the upcast shaft. If these be comparatively small a considerable amount of water guage will be required, in order to give velocity through the contracted areas. If, on the contrary, they be large, we may pass large volumes of air with a low degree of water guage. Now the diameter of the blast pipe must be ruled first by the diameter of the jet, and secondly by the degree of water guage at which the air reaches the blast pipe. By diminishing the blast pipe we may get almost any amount of water guage, so long as we shut off the access of the air to the blast pipe; but the moment the air is admitted the water guage falls, and the quantity of air passed through the apparatus is most materially affected by the diameter of the blast pipe. Thus a very small blast pipe gives a large statical but a low dynamical effect. This is a point which seems entirely to have been lost sight of by the advocates of the Steam Jet, who argue that because they can obtain a degree of exhaustion equal to a column of several feet of water, therefore they can drive or force an illimitable quantity of air through a narrow passage. We admit the premise, but deny the

conclusion. The following experiment is perfectly conclusive:—With a jet of $\frac{35}{100}$ diameter, working in a closed blast pipe of 1 inch diameter, and a pressure of steam of 10lbs. we get an exhaustion of 30 inches of water, if now the air be admitted to the back of the jet, the total effect is 62 cubic feet of air passed through the blast pipe per minute: that is to say, that if the area of an upcast shaft of 3 feet diameter, equal to 1296 circular inches, be fitted with 1296 jets, of the above diameter, and the steam be used at 10lbs. pressure, we could, by closing the downcast, create an exhaustion of 30 inches of water in the mine, but on opening the downcast we could only get 80·352 cubic feet of air per minute, supposing the friction of the workings to be nil, and this, by the way, with an expenditure of steam equal to the evaporation of 12,720 cubic feet of water per hour. Such a case could of course never occur in practice, but I mention it to give an idea of the incompatibility of very high exhausting powers with the transmission of large volumes of air.

But to return to the question of the effect of varying the diameter of the blast pipe. As a first principle, we may lay it down that the larger the area of the blast pipe, as compared with the jet, within certain limits, the lower will be the water gauge and the greater the quantity of air moved. The limit just mentioned is that the diameter of the blast pipe shall not exceed the largest diameter of the cone of steam, at a point where that steam still retains a velocity equal to the velocity of the air passing out of the blast pipe. When, however, as is practically the case in ventilation, a certain amount of water guage is required to overcome the friction of the workings, it will be necessary to contract the blast pipe to obtain this water gauge.

The diameter of the blast pipe should also be dependent upon the pressure of the steam. If steam be used at a high pressure, a larger blast pipe is required to gain the maximum effect. If, for instance, we have a jet of $\frac{7}{100}$ playing in a blast pipe of 1 inch, with a pressure of 5lbs., we may more than treble the effect of that same jet by using a blast pipe of 2 inches diameter, but if the steam be used at a pressure of 50lbs. per square inch, in order to treble the effect of the 1 inch blast pipe we must use a blast pipe of upwards of 4 inches diameter. These numbers must be taken simply as approximation, and are only mentioned to give definite ideas of the mode of action of the steam.

We will now endeavour to investigate more closely the relations

which exist between and unite the various elements of the question : viz., the quantity of air moved, the water gauge, the diameters of the jet and blast pipe ; and, lastly, the expenditure of steam.

If we conceive a pipe of any given area, closed at one end, and at a distance of eight times its diameter from the other, a steam jet placed concentric with it and playing outwards, we may, by a proper proportionment of the area of the jet to that of the pipe, obtain a certain amount of vacuum in the closed end; if now the closed end be opened, the air will rush into that partial vacuum with a velocity represented by $m \sqrt[n]{h}$; m being a constant, and h the amount of exhaustion measured by the amount of water guage. If, now, the steam jet keeps up the exhaustive action, the velocity will continue uniform, and the quantity of air passing the blast pipe will be $\text{A}\ m \sqrt[n]{h}$, A being the area of blast pipe. The question then resolves itself into the determination of the index of h and m. Now it is obvious that h is some function of the area of the blast pipe, and that the larger we take a the less will be h. Let us therefore assume $h = \varphi\left(\frac{1}{\text{A}}\right)$. It is further obvious that h being an effect produced by the action of a jet of steam, and the action of that jet being a function of the area (a) of the jet, and also of the pressure P we may also say h is a function of that area and pressure or $h = \varphi'(a)\,\varphi''(\text{P})$, we have therefore $h = \varphi'(a)\,\varphi''(\text{P})\,\varphi\left(\frac{1}{\text{A}}\right)$.

In order to obtain practical data whereby to ascertain the nature of these functions, and the amount of their co-efficients, a vast number of experiments, amounting in the whole to upwards of 3,000 observations, were made with the apparatus above described. After proceeding a long way with these experiments, and attempting their reduction, several very extraordinary and anomalous results were manifested, arising, as was at length discovered, from two causes; first, the uncertainty of action of the anemometer; and secondly, the leakage into the apparatus, which it was almost impossible to avoid. The most minute aperture had a most sensible effect upon the amount of water guage ; and the anemometer, though tolerably correct at high velocities, yet indicated on several occasions velocities so far from what must have been the real ones, and at low velocities was so uncertain in its action, that recourse was at length had to another mode of experimenting. Removing the anemometer and the slides, and closing up the box altogether, a series of longitudinal openings or ports were made in the top of the box, each about 6 inches long by $\frac{1}{2}$ inch wide. These

were closed by slides made perfectly tight with a little red lead, a water gauge was attached as before to the box. The mode of experimenting was as follows :—The jet being put in action at a certain pressure, a certain exhaustion was the result, indicated by the rise of the water gauge. This being registered as the absolute exhaustion power of that jet at that pressure. The pressure was increased, and the result again noted, until a series of observations were obtained, showing the exhaustive power as varying according to the variation of pressure.

In the next place, to ascertain the quantity of air passing through the apparatus, the jet was set in action, at various pressures from 5lb. up to 60lbs, and in each case the slide in the top was opened until the water gauge indicated a rarefaction of $\frac{1}{2}$ inch of water; the amount of opening of the slide was then measured, and from thence the quantity of air passing into the box calculated by the ordinary rules for the motion of elastic fluids.

This was repeated for water gauges of 1 inch, $1\frac{1}{2}$, and 2 inches.

The experiments were then repeated with the same jet, but with blast pipes of various diameters and lengths, the latter, however being found, if not very great, to have little effect upon the results.

The like process was repeated with jets of various sizes, so as to compare the results of one with another.

From these observations I trust to be able to establish a formula which will represent the power of any jet under any circumstances, but owing to the first experiments being vitiated, as above mentioned by the leakage and other causes, those which could be depended upon came too late to allow me to lay the results before this meeting in such a form as I would wish.

I will at present only lay before you, first a table No. 1, shewing what I have before termed the statical effect of the jet, or the absolute amount of exhaustive power. I have selected two jets, one of $\frac{7}{100}$ and another of $\frac{225}{1000}$ of an inch diameter. Their areas varying as 1 to 10 nearly. The exhaustive power of each of these jets were tried in blast pipes of the following diameters, $\frac{3}{4}$, 1, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4 inch: and at the pressures of 5, 10, 20, 40, and 60lbs., and the results recorded in inches of water. We may

compare the effect of the two jets by comparing the amount of water gauge, each produced under like circumstances. I have prepared a table (No. 2) shewing this.

TABLE No. 1.

Table shewing the exhaustive power of two Jets in various sized Blast Pipes.

Diameter of Jet.	Dia. of blast pipe.	Ratio of Areas of blast pipes.	Ratio of area of blast pipe to jet.	Pressure of Steam in lb. per square inch. 5	10	20	40	60	
0·07	¾ in.	0·55	1/112	2·38	4·37	7·18	13·75	21·00	Inches of water
	1	1·00	1/200	1·50	2·62	4·56	8·50	12·18	
	2	4·00	1/800	0·40	0·66	1·10	1·97	2·75	
	2½	6·25	1/1300	untried	0·47	0·75	1·32	1·88	
	3	9 00	1/1800	0·20	0·31	0·53	0·97	1·32	
	3½	12·25	1/2500	0·15	0·28	0·44	0·75	1·00	
	3⅞	15·00	1/3000	0 13	0·22	0·35	0·60	0·82	
0·225	2	4·00	1/80	2·37	4·50	8·25	16·25	24·00	
	2½	6·25	1/130	1·63	3·13	5·50	10·87	15·50	
	3	9 00	1/180	1·10	2·00	3·75	6·87	10·25	
	3½	12·25	1/250	0·87	1·63	2·87	5·19	7·63	
	3⅞	15·00	1/300	0·63	1·12	2·12	4·00	5·87 ?	

Diameter of jet.	Dia. of blast pipe.	Ratio of Areas of blast pipes.	Ratio of area of blast pipe to jet.	Pressure of steam in lb. per square inch. 5	6	7½	9¼	10	12½	15
0·225	¾	0·55	1/112	15·20	19·15	..	30·00	..	..	..
	1	1·00	1/20	9·37		14·00	..	19·00	23·00	27·00

From which it appears that whilst the areas of the jets are as 10 to 1, and, consequently, the expenditure of steam in that ratio the exhaustive powers, are at low pressures, in a ratio varying between 6½ and 5 to 1, and at high pressures, in a ratio varying between 9 and 7 to 1, according to the areas of the funnels or blast pipes. The deduction from this is that the smaller the diameter of the jet the greater the effect from a given volume of water.

TABLE No. 2.

Relative effect of different sized Jets in exhaustive power.

Area of Jets as 1 *to* 10.

Diam. of Blast Pipe.	Pressure of Steam.				
	5	10	20	40	60
$\frac{3}{4}$ inch.	$\frac{1}{6{\cdot}51}$	$\frac{1}{7{\cdot}09}$	..	..	..
1 inch.	$\frac{1}{6{\cdot}25}$	$\frac{1}{7{\cdot}23}$	..	..	..
2 inch.	$\frac{1}{5{\cdot}93}$	$\frac{1}{6{\cdot}75}$	$\frac{1}{7{\cdot}50}$	$\frac{1}{8{\cdot}25}$	$\frac{1}{8{\cdot}73}$
$2\frac{1}{2}$ inch.	..	$\frac{1}{6{\cdot}66}$	$\frac{1}{7{\cdot}33}$	$\frac{1}{8{\cdot}24}$	$\frac{1}{8{\cdot}24}$
3 inch.	$\frac{1}{5{\cdot}50}$	$\frac{1}{6{\cdot}45}$	$\frac{1}{7{\cdot}07}$	$\frac{1}{7{\cdot}08}$	$\frac{1}{7{\cdot}76}$
$3\frac{1}{2}$ inch.	$\frac{1}{5{\cdot}80}$	$\frac{1}{5{\cdot}82}$	$\frac{1}{6{\cdot}50}$	$\frac{1}{6{\cdot}92}$	$\frac{1}{7{\cdot}63}$
$3\frac{3}{5}$ inch.	$\frac{1}{5{\cdot}00}$	$\frac{1}{5{\cdot}10}$	$\frac{1}{6{\cdot}06}$	$\frac{1}{6{\cdot}66}$	$\frac{1}{7{\cdot}16}$

From this table it may also be seen that the amount of exhaustion varies nearly in the ratio of the pressure, and practically it may be assumed that this is the case. If then the velocity be as the square root of the exhaustive power which ratio it cannot exceed, it follows that the quantity of air is as the square root of the pressure.

It may be further shown that the exhaustive power varies very nearly inversely as the area within the limits of practice, therefore the exhaustive power is as the pressure divided by the area, or as $\frac{p}{a}$ but the velocity being as the square root of the exhaustive power we get

$$v \times \sqrt{\frac{p}{a}}$$

but volume of air = velocity × area therefore volume of air is as $\sqrt{}$ pressure × $\sqrt{}$ area.

The assumption that the velocity of the air rushing into the blast pipe being as the $\sqrt{}$exhaustion is the most favourable that can be made, the probability being that it will be a still lower ratio, but in the absence of the true law we will assume the above as the most favourable to the effect of the jet; that is to say, that the air follows into the blast pipe with the velocity due to the amount of exhaustion.

We will now examine the effect of two jets of different areas with a view to ascertain their relative economy in practice, and for this purpose we will assume the water gauge to be $1\frac{1}{2}$ inches of water: that is to say, that to overcome the friction of the workings of the mine, an amount of exhaustion is required equal to a column of $1\frac{1}{2}$ inches of water before any motion can take place. It is therefore evident that it will be only the excess of the exhaustive power of the jet above this fixed amount that will produce the motion of the air. If now we take the jet of $\frac{7}{100}$ diameter, pressure of steam, 20lbs., and try it in various blast pipes, we will find that its maximum motive effect is when the diameter of the blast pipe is $1\frac{1}{4}$ inch.

From the table No 1 we find for this jet and pressure with a blast pipe of 1 inch diameter, an exhaustion of 4·56 inches of water, and reducing this in the proportion of the area, we will find the exhaustive power in the blast pipe of $1\frac{1}{4}$ inches $= 4{\cdot}56 \times (\frac{1}{1{\cdot}25})^2 = 2{\cdot}92$ inches, therefore the effective exhaustion $= 2{\cdot}92 - 1{\cdot}50 = 1{\cdot}42$ inches, but the quantity of air passing at this degree of exhaustion if A be the area, and H the water gauge both in inches $= 28{\cdot}75\ A\ \sqrt{H} = 28{\cdot}75 \times 1{\cdot}227 \times \sqrt{1{\cdot}42} = 42$ cubic feet per minute nearly, or if we assume the co-efficient of contraction for the entrance of the air into the blast pipe $= 0{\cdot}9$ we have the quantity of air moved $= 42 \times 0{\cdot}9 = 37{\cdot}8$ cubic feet per minute.

Now the expenditure of water with this jet may be found from the formula No 1 (A), taking $c = 0{\cdot}9$

Volume of water expended per hour $= 1{\cdot}572\ a\ \sqrt{(p^2 - 10{\cdot}46\,p - 63{\cdot}28)}$ when a = area of jet in inches, p = pressure of steam, including pressure of atmosphere in lbs. per square inch, whence we derive from this jet

Volume of water expended $= 0{\cdot}1688$ cubic feet per hour.

If now we perform the same calculation with a blast pipe of either larger or smaller diameter, we shall find a less effect produced, consequently, the diameter of $1\frac{1}{4}$ inch under the above circumstances, produces the maximum of effect.

Proceeding in like manner we shall find that with the same jet and pressures of steam of 5lbs. and 60lbs. per square inch, the expenditure of water and the quantity of air moved to be as in the following table. The results of similar calculations with the jet of a diameter, ·225 inches are also tabulated, and in the succeeding table they are reduced to the effect of one cubic foot of water per hour, in cubic feet of air moved per minute.

TABLE No. 3.

	Pressure of Steam 5lbs.		Pressure of Steam, 20lbs.		Pressure of Steam, 60lbs.	
	Cubic ft. of water expended ℔ hour.	Cubic ft. of air moved ℔ minute.	Cubic ft. of water expended ℔ hour.	Cubic ft. of air moved ℔ minute.	Cubic ft. of water expended ℔ hour.	Cubic ft. of air moved ℔ minute.
Jet. Diam. = 0·07 In.						
Blast Pipes.						
Diam. for 5lbs. = 0·625 In.						
,, 20 ,, = 1·250	0·0672	11·16	0·1688	37 8	0·4182	100·8
,, 60 ,, = 2·110						
Jet. Diam. = 0·225						
Blast Pipes.						
Diam, for 5lbs. = 1·750	·6921	78·3	1·738	311·4	4·307	801·
,, 20 ,, = 3 625						
,, 60 ,, = 5·750						

TABLE No. 4.

Volume of Air in cubic feet per minute, moved by the expenditure of 1 cubic foot of water per hour.	Diameter of Jet = 0 07 in.			Diameter of Jet = 0·225 in.		
	Pressure 5lbs	Pressure 20lbs.	Pressure 60lbs	Pressure 5lbs.	Pressure 20lbs.	Pressure 60lbs.
	165	224	241	113	179	186

Hence again we see the advantage of subdividing the jets and working at a higher pressure. The difference between the effect of the expenditure of a cubic foot of water in the larger jet as steam at 5lbs. pressure, and in the smaller jet at 60lbs. pressure, being as 113 to 244 or as 1 to 2·1.

If we now enquire the amount of power required to move a certain amount of air, say 120,000 cubic feet per minute, the column in the water gauge being, as above, $1\frac{1}{2}$ inch, we shall obtain it by dividing 120,000 by 241, and we find it will require the evaporation of nearly 500 cubic feet of water per hour, and assuming that 1lb of coal will evaporate 8lbs. of water or $7\frac{8}{10}$lbs. of coal 1 cubic foot, we shall have a consumption of 3,900lbs. $= 34\frac{1}{2}$ cwts. per hour nearly $=$ 2894 cubic feet of air per minute for each ton of coals in 24 hours. The amount of boiler power to evaporate this quan-

tity of water, allowing 7 feet of heating surface per cubic foot of water per hour, will be about 13 boilers, each 6 feet diameter and 30 feet long.

I do not wish the above figures to be taken as absolutely correct, but as more favourable towards the steam jet than the actual results would otherwise be, as I have based and carried out the calculations upon the theoretical velocity of the air (reduced by the high co-efficient of ·9) rushing into the blast pipe, which can never be attained in practice.

If, on the other hand, we compare the jet of the diameter 0·225, working at a pressure of steam of [illegible] lbs. per square inch, we should require, for the same amount of ventilation, an exhaustion of fuel more than two-fold. This difference in the result, arising from the difference in the mode of application, show how difficult it is to compare the results stated in evidence with each other, or with any other system of ventilation; and this emphatically calls for a thorough investigation of the laws of action of the jet, so to enable the practical man to apply it under circumstances to obtain the maximum effect from a cubic foot of water.

The results of the table No. 4 are somewhat startling when compared with the experiments of Mr. Vivian, detailed in the Blue Book of the Lord's Committee of 1849, and the object of which was to determine the actual quantity of air passed through the apparatus in a given time. In Mr. Vivian's evidence he states, in answer to question 4357, that the highest amount of duty obtained with a jet of $\frac{1}{8}$ inch area and steam of 50lbs. per square inch and under an exhaustion of $1\frac{1}{2}$ inch column of water gauge, was equal to 35,856 cubic feet per minute for the whole power of the boiler; and he also states that the boiler was equal to the supply of 36 such jets, therefore for each jet the quantity of air moved was $\frac{35856}{36} = 996$ cubic feet per minute. Now the expenditure of water by such a jet would be by our formula No. I. (A)

$$Q = 1{\cdot}572 \times \tfrac{1}{64} \sqrt{(65^2 - 10{\cdot}46 \times 65 - 63{\cdot}28)} = 1{\cdot}45 \text{ cubic feet per hour, therefore}$$

cubic feet of air per minute by the expenditure of 1 cubic foot of water per hour

$$= \frac{996}{1{\cdot}43} = 690 \text{ cubic feet.}$$

Now it will be observed that with one jet of 0·07 diameter, which being only about $\frac{1}{3}$ of the area of Mr. Vivian's jet, is consequently more economical in its action, we only get 241 cubic feet of air by 1 cubic foot of water, or only about $\frac{1}{3}$ of the effect recorded by Mr. Vivian.

So startling a discrepancy led me to a reconsideration of the mode of experimenting, adopted both by Mr. Vivian and myself, and so to the perception of a fallacy in our ideas of the action of the apparatus.

The fallacy consisted in imagining that because the air reached the jet in the apparatus under the same degree of rarefaction as in the mine, therefore in both cases the jet was doing the same amount of work. It is, however, not so. In the apparatus the rarefaction arises solely from contracting the orifice for the admission of air to such an extent, that whilst the air is passing through the box it is distended to the amount of water gauge. There is no appreciable friction, and however low the exhaustive power of the jet a certain amount of air due to that exhaustive power will pass through the apparatus. On the other hand, in the mine the amount of rarefaction at the bottom of the upcast shaft, *i.e.*, the height of the water gauge arises from the friction and resistance of the air through the workings, and no air whatever can pass through the blast pipes until an amount of rarefaction equal to the amount of water gauge is produced, and then the quantity of air passed through will only be that due to the excess of the exhaustive power of the jet, above the water gauge due to the friction and resistance of the air. It is, consequently, obvious that in the mine the jet has an amount of work to do widely different from what it has in the apparatus. In the apparatus the air has free access to the aperture, and is simply rushing directly into a partial vacuum, with no more friction or resistance than it meets with at the entrance, but in the mine it arrives at the jet through a long and tortuous course, and, consequently, with a large amount of friction and resistance. It follows, therefore, that for practical data, the apparatus as used by Mr. Vivian and by myself, to ascertain the quantity of air actually passing through a mine is quite unsuited, and that to render the case analogous to the mine we must create the column of water in the water gauge in a similar way, viz., by resistance to the passage of the air. These remarks do not apply to what I have termed the vacuum experiments, or these experiments made to ascertain the absolute amount of exhaustive power of each jet. These experiments affording us data whereby to find the absolute power given out by the jet ; we may deduce therefrom the practical maximum of effect obtained by making due allowance for the friction and resistance. If, then, it shall appear that the maximum theoretical effect is insignificant, we may, *a fortiori*, infer that the practical result, after making the necessary deductions for friction and imperfect action, will be still less important. Now we know that the air cannot pass into the blast pipe with a velocity exceeding

that due to the amount of rarefaction therein; we know, moreover, that the friction and resistance in the workings of the mine requires a certain amount of water gauge before any motion of the air through them can take place; we further know, from experiments made for the direct purpose, what is the maximum amount of exhaustion of a jet at a given pressure of steam and in a given blast pipe; and lastly, we know from the laws of motion of elastic fluids the quantity of air that will pass through any given area with a given amount of exhaustion. We are, therefore, in a condition to determine the maximum of useful effect, though that maximum, may not indeed be obtained in practice, owing to improper adaptations or other causes.

I will not at present go into any further deductions from these experiments, trusting ere long to give them in a much more complete form, and at the same time to enter upon a comparison between the steam jet, and other modes of ventilation; including probably a review of some portions of the evidence given before the parliamentary committee of last session, and the report founded thereon—a report of which I will only at present say, that it possesses the peculiarity of asserting as fact, that which the evidence shews still to be in the domain of opinion.

Before, however, concluding, I will refer to two points which have been much insisted upon by the advocates of the steam jet, as conclusive evidence of its superior powers. The first is its action as applied in the Locomotive Engine for the creation of the large evaporative power of its boiler. The second is its action in Seaton Delaval Colliery.

With respect to the first, I will ascertain the actual amount in volume and density of the gases passing through the chimney in a given time, and compare this with the actual power expended by the steam, as a jet, as it escapes from the blast pipe. For this purpose I take an experiment recorded in the last Edition of Tredgold, made on the Caledonian Railway, on the Engine No. 15.

Here we have the following data:—

Water evaporated per minute, = 1·4 c. ft. = 40·34 cubic inches per second.
Coke burnt per minute, = 9lb. = 0·15 ,, ,,

This coke may be assumed to consist of—

Carbon	92
Water.....	5
Ash.....	3
	100

Consequently the Carbon consumed per second = 0·15 × 0·92 = 0·138lb.

Now, in the combustion of this carbon, it combines with oxygen in the proportion of 37·66lbs. of carbon to 100lbs. of oxygen; consequently, the quantity of oxygen required = 0·138 × $\frac{100}{37·66}$ = 0·36lb. of oxygen; but 1 cubic foot of oxygen at 32° and 14$\frac{3}{4}$lbs. per square inch, weighs 0·0842lb., ∴ as 0·0842 : 1 : : 0·36 : 4·27 cubic feet required for 0·138lb. of carbon; but 100 cubic feet of air contain 21 cubic feet of oxygen, ∴ as 21 : 100 : : 4·27 : 20·3 cubic feet of air required for the combustion of the 0·15lbs. of coke, but as only two-thirds of the whole quantity of air is consumed, we must have 20·3 × $\frac{3}{2}$ = 30·45 cubic feet of air required per second. We have, therefore, we may say, 30 cubic feet of air passing between the grate bars per second, of which 20 cubic feet is decomposed, and 10 cubic feet pass off free.

We will assume the temperature in the chimney to be 600°.

The volume of free air = 10 [1 + 0·002083 × 600] = 10 × 2.25 = 22 5 =	22·5
But 20 feet of air contains 15·8 cubic feet nitrogen and 4·2 oxygen, and 15·8 cubic feet nitrogen at 600° becomes 15·8 × 2·25 ..... =	35·5
And 4·2 oxygen unites with carbon and forms 4·2 cubic feet of carb. acid, which at the temperature of 600° = 4·2 × 2·25 ..... =	9·4
Total volume of gases per second	67·4

Now, in order to ascertain the velocity of these gases through the chimney, we must divide the volume by the area of the chimney, reduced by a certain coefficient of contraction. This may be assumed at 0·8 ∴ reduced area = 1·07 × 0·8 = ·856 ∴ volume = $\frac{67·4}{8·56}$ = 79 feet per second nearly = v. Now to obtain the mechanical effect of this, we have the equation

H.P. = 0·0095 w h where w = volume of fluid emitted per second, in cubic feet, at the pressure corresponding to the velocity

h = pressure corresponding to velocity in inches of water = 0·003 $v^2 d$ where v = velocity and d = weight of 1 cubic foot of the fluid.

Now to find d we have—

							lbs.
10 c. feet of air unconsumed expanded to 22·5 c. feet, and weighing 10 × ·0766 =							·7666
15·8	,,	Nitrogen	,,	35·5	,,	,, 15·8 × ·075 =	1·1920
4·2	,,	Carb. Acid Gas	,,	9·4	,,	,, 4·2 × 0·117 =	·4914
				67·4			2·45

∴ d = $\frac{2·45}{67·4}$ = 0·0363

∴ h = ·003 × 79^2 × ·0363 = 0·67965

∴ H. P. = ·0095 + 67·4 × 0·67965 = ·4352

But the force expended is the whole steam passing through the blast pipe,

and supposing the average pressure to be 4lbs., the relative volume = 1411 ∴ the volume of steam per second = $\frac{1\cdot4}{60} \times 1411 = 32\cdot9$ and the area of blast pipe being $\frac{15\cdot9}{144} = 0\cdot11$ square feet, we get velocity of exit = $\frac{32\cdot9}{0\cdot11} = 300$ nearly.

But $d = \frac{62\cdot5}{1411}$lbs. ∴ $h = \cdot003 \times 300^2 \times \frac{62\cdot5}{1411} = 12$

∴ H.P. = $\cdot0095 \times 32\cdot9 \times 12 = 3\cdot750$

∴ effect produced : force expended :: $\cdot4352 : 3\cdot750$

:: $11\cdot6 : 100$

But if we compare the result with the actual quantity of steam expended, we find that the effect of an evaporating power of 84 cubic feet of water per hour gives $67\cdot4 \times 60 = 4044$ cubic feet of gases in their expanded state passed through the chimney per minute, or 1800 cubic feet before expansion; and if we allow for the difference of density as compared with atmospheric air, and take the temperature at 62°, which makes the thing analogous to the ventilation of a mine, we get 3040 cubic feet of air passed per minute by the expenditure of 84 cubic feet of steam per hour, or $36\frac{1}{2}$ cubic feet of air per minute for 1 cubic foot of water per hour.

As another instance, I take an experiment recorded in the report of the Gauge Commissioners, and made by Mr. Gooch, on the Great Western Railway.

Here we have—

Water evaporated per hour..... 196 cubic feet.

And allowing 1lb. of coke to 7lbs. of water—

Coke consumed per second = $\frac{196}{7} \times \frac{62\cdot5}{3600} = 0\cdot486$lbs.

And going through the calculation in the same way as in the last case, we find the result to be equivalent to 9849 cubic feet of air passed through the chimney, or as we may call it, the upcast, by the expenditure of 196 cubic feet of water per hour = $50\frac{1}{4}$ cubic feet of air for 1 cubic foot of water evaporated per hour. By comparing these results with those given in Table No. 4, and assuming that the resistance to the air passing through the fire grate and tubes in the locomotive engine is equal to $1\frac{1}{2}$ in. water gauge, and corresponding therefore to the resistance of the mine, we see that the one is in round numbers only 1-7th, and the other 1-5th, of the effect of the same quantity of water expended in a jet of $\frac{7}{100}$ inch diameter, a result for which we are of course fully prepared by what has been previously stated, and arising from the low pressure of the steam and the large size of the jet. The proportion, then, between the power expended and the effect produced in the locomotive engine, is enormously unfavourable, and it is only sur-

prising that this application of the jet should ever have been used as an argument in its favour.

If some gentlemen, before giving their evidence, would go into a few simple calculations of the above nature, they would spare the nation some expense in printing, and would prevent much really useful information being consigned to that literary tomb of all the Capulets, a parliamentary blue book.

We will now go to Seaton Delaval Colliery, and try to discover in how far the result of the application of the jet there warrants the encomiums bestowed upon it. We find there the steam is applied in 25 jets, each $\frac{3}{8}$ inch diameter; therefore, the aggregate amount = 2·76 inches.

Taking the data from the trial recorded in Mr. Thomas John Taylor's evidence in 1849, we have the consumption of coal to supply the jets alone 4 cwt. per hour, and allowing 10 lbs. of coal to 1 cubic foot of water we would get an evaporation of 44.8 cubic feet per hour.

The boiler is stated by Mr. Forster to be about 28 feet long and 6 feet wide. If this be the case, it is probable that both boilers were used in Mr. Taylor's experiments, as the above evaporation considerably exceeds that of one such boiler, being about one cubic foot of water per hour, per 5 feet of heating surface. The average evaporation of one such boiler would be about 32 cubic feet per hour, but for our present purposes, we will assume that 45 cubic feet per hour passed through the jets. Taking, then, the formula No. 1 A. based upon Pambour's formula for relative volumes, and taking the co-efficient for contraction at 0·9 we get

$$45 = 1{\cdot}572 \times 2{\cdot}76 \sqrt{(p^2 - 10{\cdot}46\, p - 63{\cdot}28)}$$

whence we find $p = 19{\cdot}32$ lbs. ℔ square inch.

and this being the absolute pressure, we must deduct the atmospheric resistance, or 14·75, and we find the effective pressure = 4·57 lbs.; consequently, even with the evaporation of 45 cubic feet per hour, the steam could not issue from the jets with an effective pressure of more than 4·57 lbs. per square inch, and the result as an impulsive power at that pressure, must have been very insignificant. Had one boiler only been used with an evaporative power of 32 cubic feet per hour, the pressure of the steam would not have exceeded $2\frac{2}{3}$ lbs. per square inch above the atmosphere.

But, admitting that the steam issued from the jets with a velocity due to a pressure of 5lbs., and admitting further, which, however, is not the case, that the steam was as economically applied in the $\frac{3}{8}$ jets, as in the larger jet of table No. 4, we will find that assuming that the friction of the workings of the mine was $1\frac{1}{2}$ inch of water gauge, the quantity of air passed by the mechanical force of the steam was, as in the above table, 113 cubic feet per minute for each cubic foot of water evaporated per hour, *i.e.*, with an evaporation of 45 cubic feet per hour = 5085 cubic feet per minute, or with an evaporation of 32 cubic feet per hour = 3616 cubic feet, of air per minute.

Let us now examine what effect is due to the heating power of the steam in this case.

1 lb of water converted into steam contains as much heat as would raise 4,255lbs. of air 1°, and since 1lb of air at 62° is equal to about $13\frac{1}{3}$ cubic feet, we obtain $42{,}55 \times 13\frac{1}{3} = 56{,}733$ cubic feet of air raised 1°, but the total quantity of water evaporated being 45 cubic feet per hour, or 47lbs. per minute, and the quantity of air per minute being 86,000 cubic feet, we find that the heat contained in the steam would raise this quantity of air $\frac{56{,}733 \times 47}{86000} = 31°$. If to this we add the heat contained in the steam from the engine which also passes into the up-cast shaft, and the heat from the boiler fires, we shall find enough, and more than enough, to account for the amount of ventilation from the temperature alone. But we may estimate this more accurately by the amount of fuel consumed. It is stated by Mr. Thomas John Taylor, that he found the mean temperature of the up-cast shaft to be 152°, that of the down-cast being $62\frac{1}{2}°$. The consumption of fuel for the jets and engine was stated at 1,232lbs. per hour, and for the jets alone, at 448lbs. per hour.

We may here remark, in passing, the extraordinary descrepancy or disproportion between these two statements; the boilers are stated to be of the same size, and yet the consumption of the one would appear to be nearly double that of the other.

However, taking the facts to be as recorded, and knowing that 1 lb. of coal in its combustion gives out as much heat as will raise 11lbs. of water 1150° we get the following result :—

Consumption of 1232lbs. per hour will raise 259,325lbs. of water, 1° per minute.
,, 448 ,, 94,875 ,, 1°
or equal to 12,706,925 cubic feet of air per minute, raised 1°
and 4,648,875 ,, ,, ,, 1° respectively.

If now we divide these numbers by the quantity of air passing, we shall find that quantity, viz. :—77,450 cubic feet raised 164°, and 60° respectively, which, added to the temperature of the down cast shaft, give 226½° and 122½° respectively. Now, as Mr. Taylor states the mean temperature of the upcast shaft to have been 152°, two things are evident, first, that when both jet and engine are at work, the heat expended is much more than sufficient to produce the ventilation, and is considerably more than is apparent in the shaft; and secondly, that when the jets alone are at work, the fuel stated to be used is insufficient theoretically, and without any loss of temperature from conduction of the shaft, to give the temperature actually observed.

As a further deduction, we may observe, that a considerable portion of heat must pass off latent in the steam, which escapes uncondensed, or in the large amount of watery vapour combined with the air.

By the application of the formula No. III., we get the equivalent water gauges corresponding to these temperatures 2·36 inches and 0·93 inches respectively, and upon this we may remark that setting aside the mechanical force of the jets, there ought to result an immense difference in the ventilation of the mine under the above circumstances, and this brings us to the consideration of the last point upon which we shall at present dwell, viz., the prejudicial action of the steam jet, or its action as actually impeding the ventilation due to the rarefaction by heat. The mean temperature of the shaft being 152° the weight of steam in a cubic foot of air. at that temperature, is about 0·013lbs. and its volume 1·666 cubic feet, consequently, we must have one of two results, either an increase of velocity in the upcast shaft, so as to pass 1⅔, instead of 1 cubic foot or an increase of density of the air and vapour. The real effect is a combination of these two, and of course, an increased resistance in the shaft. This increase is greater the higher the temperature, and to some extent prevents the large increase of ventilation which would otherwise result from the greatly increased consumption of fuel when both engine and jets are in operation.

Lastly, it must be observed that if we take the consumption of water by the jets alone at 45 cubic feet per hour, this weight of 45 cubic feet has to be lifted by the power of ventilation from the bottom to the top of the upcast shaft every hour. This is equal to 47lbs. raised 600 feet per minute = nearly $\frac{9}{10}$ of horse power, and is equivalent to a water gauge

of 0·18 inches, and this is equivalent to a difference of temperature of $11\frac{1}{2}°$ between the upcast and downcast shafts.

The results, then, of the above calculations, are as follows :—

That the steam expended by the jets does not issue therefrom at a pressure exceeding 5lbs. per square inch.

That its mechanical effect under these circumstances, cannot exceed, but may fall short of 5,000 cubic feet per minute.

That this mechanical effect is probably more than counterbalanced by the force required, to lift the water from the bottom to the top of the shaft, and by the increased resistance due to the volume of the steam passing off in combination with the air at 152°.

And lastly, that the amount of fuel consumed is more than sufficient to produce, by the ordinary furnace, the whole effect obtained by the more expensive and more dangerous apparatus of steam boilers.

FORMULA I.

Expenditure of water by a jet of steam.

Let P = pressure of steam in pounds per square foot including atmospheric pressure.

A = area of jet in inches.

C = co-efficient for contraction.

v = volume of steam expended at pressure P.

V = volume of water.

V′ = velocity of efflux of steam in feet per second.

then $V' = 8 \sqrt{\frac{P-2124}{\text{weight of cubic foot of steam.}}}$

1st. By Pambour's formula for relative volume

$$V = \frac{v}{\frac{10000}{1{\cdot}421 + {\cdot}0023\,P}} = \frac{1{\cdot}421 + {\cdot}0023\,P)\ v}{10{,}000}$$

therefore weight of cubic foot of steam at pressure P $= \frac{62{\cdot}5\,(1{\cdot}421 + {\cdot}0023\,P)}{10{,}000}$

$$\therefore\ V' = 8 \sqrt{\frac{(P - 2124) \times 10000}{(1{\cdot}421 + {\cdot}0023\,P) \times 62{\cdot}5}}$$

$\therefore$ volume of steam expended per hour $= 60 \times 60 \times C \times \frac{A}{144} \times V'$

and volume of water $= \frac{3600\,CAV'}{144 \times \frac{10000}{1{\cdot}421 + {\cdot}0023\,P}}$ and substituting for V′ its value.

$$\text{volume of water } V = \frac{3600\,CA}{144} \times 8 \sqrt{\frac{(P - 2124) \times (1{\cdot}421 + {\cdot}0023\,P)}{62{\cdot}5 \times 10000}}$$

$$= {\cdot}253\,CA \sqrt{{\cdot}0023\,P^2 - 3{\cdot}464\,P - 3018}$$

or if p = lbs. per square inch $= \frac{P}{144}$

$$\text{volume of water} = {\cdot}253\,CA \sqrt{47{\cdot}69\,p^2 - 498{\cdot}8\,p - 3018}$$

$$= 1{\cdot}747\,CA \sqrt{p^2 - 10{\cdot}46\,p - 63{\cdot}28} \quad \ldots\ \ldots\ \ldots\ldots\ldots\ldots \quad (A)$$

or if Tate's formula for relative volume $= 12{\cdot}5 \times \frac{20570}{p^{\,{\cdot}9301}}$ be used, we get

$$\text{volume of water} = 2\,C\,A = \sqrt{\frac{23040\,(p - 14{\cdot}75)}{12{\cdot}5 + \frac{20570}{p^{\,{\cdot}9301}}}}$$

$$= 85{\cdot}86\,C\,A \sqrt{\frac{(p - 14{\cdot}75)\,p^{\,{\cdot}9301}}{1646 + p^{\,{\cdot}9301}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (B)$$

C may be taken $= 0{\cdot}90$

FORMULA II.

For the quantity of air passing through a given area under a given pressure

Let A = area in inches.

P = pressure of the atmosphere = 14·75 × 144 = lbs. per square foot.

p = pressure opposed to passage of air, therefore

P − p = excess of pressure which gives motion.

W = weight of a cubic foot of the air at pressure P and temperature 32°

∴ weight at any other pressure P′ and temperature t

$$= W \times \frac{P'}{P} \times \left(\frac{1}{1 + \frac{t - 32}{482}} \right)$$

but velocity of efflux $v = \sqrt{2\, g \frac{P - p}{W}}$ in feet per second.

and substituting for P any other value P′ and for W its corresponding value we get

$$v = \sqrt{2\, g \frac{P' - p}{W \frac{P'}{P} \times \frac{1}{1 + \frac{t - 32}{482}}}}$$

$$= \sqrt{2\, g \frac{P' - p}{\frac{W\, P'}{P} \times \frac{1}{1 + \frac{t - 32}{482}}}}$$

$$= \sqrt{2\, g \frac{(P' - p)\, P\, (450 + t)}{428\, W\, P'}}$$

$$= \sqrt{2\, g \frac{(P' - p)\, P}{W\, P'} \times \frac{450 + t}{482}}$$

Now, if h = height of column of water gauge, in inches of water, producing motion, we have $h = \frac{12\, P' - p}{62{\cdot}5}$ and substituting and reducing

we get $v = 66{\cdot}36 \sqrt{h \times \frac{P}{P'} \times \frac{450 + t}{482}}$

in which h = height of column of water gauge producing motion of the air

P = atmospheric pressure.

P′ = pressure of the air passed.

t = temperature of air passed.

but since in all ordinary cases we may assume $\frac{P'}{P} = 1$, without sensible error we may have

$$v = 66{\cdot}36 \sqrt{h \times \frac{450 + t}{482}}$$

and assuming t = 68° the temperature we will suppose, when the air reaches the upcast, we get

$v = 68{\cdot}9 \sqrt{h}$ and vol of air passed per minute = $\frac{A}{144} \times 60\, v$ =

$$\frac{A}{144} \times 60 \times 68{\cdot}9 \sqrt{h}$$

whence vol. of air passing = 28·7 × A $\sqrt{h}$ *without contraction.*

FORMULA III.

For the velocity of air in shafts due to rarefaction by heat.

Let T be the mean temperature of upcast shaft.

t do. downcast do.

D depth of shafts.

The expanded length $= D\left(1 + \frac{T - t}{450 + t}\right)$

column of cold air at the temperature of the downcast shaft which is equivalent to the column of hot air of the length of the upcast

$$= \frac{D^2}{D\left(1 + \frac{T - t}{450 + t}\right)} = \frac{D\,(450 + t}{450 + T}$$

column which gives motion $= D - D\,\frac{450 + t}{450 + T} = D\left(1 - \frac{450 + t}{450 + T}\right)$

$$= D\left(\frac{T - t}{450 + T}\right) = H.$$

but since air is 815 times lighter than water we get

water gauge $= \frac{D}{815}\left(\frac{T - t}{450 + T}\right)$ in feet.

and velocity of air $= 8\sqrt{D\,\frac{T - t}{450 + T}}$ in feet per second.

This formula differs from that in ordinary use inasmuch as T in the denominator is the temperature not of the downcast but of the upcast shaft.

ERRATA.

Page 13, line 10, for 80·352 read 80,352

,, 17, 10, for $v \times \sqrt{\frac{p}{a}}$ read $v \propto \sqrt{\frac{p}{a}}$

NEWCASTLE: PRINTED BY M. AND M. W. LAMBERT, GREY STREET.

NORTH OF ENGLAND INSTITUTE
OF
MINING ENGINEERS.

MONTHLY MEETING, FRIDAY, NOV. 5TH, 1852, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The Minutes of the last General Meeting and of the Council Meetings having been read.

Messrs. George Baker Forster, James B. Wilson, John Bromley Foord, Charles Mark Palmer, C. M. Bell, and Richard Heckles were elected members of the Institution.

The commencement of a Paper, by Thomas John Taylor, Esq., entitled "Proofs of the subsistence of the Fire Damp of Coal Mines in a high state of Tension in situ, and practical conclusions to be deduced from this circumstance," was read, after which the Meeting was adjourned.

N.B. The conclusion of Mr. Thomas John Taylor's Paper having been read at the Monthly Meeting, August 6th, 1853, it is printed with the proceedings of that month.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING

ON MONDAY, DECEMBER 13TH, 1852.

Durham:
PRINTED BY WILLIAM AINSLEY, 74, SADDLER STREET.

1853.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

MONTHLY MEETING, MONDAY, 13TH DEC., 1852, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meetings having been read,

Messrs. Thomas Wynne, Jas. Dickenson, Wm. Lancaster, Charles Morton, and Herbert Macworth were elected Honorary Members of the Institution, and Messrs Robert G. Reed, Wm. Peace, Jno. Thos. Woodhouse, Jno. Brough Palmer, George Green, and John Carnes, were elected Ordinary Members.

A Paper, entitled "Experiments to determine the relative value of the Furnace and Steam Jet as Ventilating Powers," was read by William Armstrong, Esq.; and the commencement of a Paper entitled "Experiments on the relative value of the Furnace and Steam Jet in the Ventilation of Coal Mines" was read by the President.

Among the strangers present were the following Inspectors of Coal Mines, namely, Mr. Wynne, for Staffordshire; Mr. Dickenson, for Lancashire; Mr. Mackworth, for South Wales, and Mr. Mathias Dunn, for the Northern District.

After the papers had been read, the President observed that the length of time which had been occupied in reading them, rendered it necessary that they should defer the general discussion until the next meeting of the Institute; but, as the government Inspectors present might

not have an opportunity of attending on that occasion, it was desirable they should now afford the Institute the benefit of any observations or suggestions they might be disposed to offer.

Mr. Dickenson.—Government Inspector for the Lancashire District, said,—There is only one point to which I think it necessary to refer. I have been in communication with Mr Darlington, who has been conducting a series of experiments, and I believe unless the Hetton experiments are conducted in the same satisfactory manner, they will not receive that attention with the advocates of the Jet, that the Killingworth experiments cannot fail to do.

The President.—I am very much obliged to you for the hint, and I will take care to attend to it.

Mr. Dickenson.—The experiments at Killingworth appear to be quite conclusive, and I think if those at Hetton are carried out in the same way, they will give satisfaction to every one. Mr Gurney himself could not I think object to them.

The President.—I will take care that all those experiments are carried out before the next meeting of the Institute.

Mr. Dickenson.—I would also suggest the use of Cylinders, which, if adopted, would render the experiments still more satisfactory.

The President.—What size Cylinders would you recommend?

Mr. Dickenson.—Mr Darlington made use of Tubes of from ten inches to one foot in diameter; the distance of those tubes being 15 inches above or in front of the Jets, according to whether the Jets were placed in a verticle or horizontal position. Mr Darlington made experiments at the Cannel Pits, as well as at Pemberton's; but those at the Cannel Pits were not so satisfactory as the others.

Mr. M. Dunn.—Was Mr Darlington satisfied with the result of his experiments?

Mr. Dickenson.—Yes, I am enabled to give you the result of Mr. Darlington's experiments at Pemberton's Pit. There the amount of the

natural Ventilation, and of the Boiler Fires was 27120 cubic feet per minute; another experiment made at the same time gave 28140 cubic feet, being an average in the two cases of 27630 cubic feet per minute. With nine Steam Jets at work, and using tubes about one foot in diameter, placed 15 inches in advance of the Jets, 37350 cubic feet per minute were produced in one experiment, and in another, 36030 cubic feet, being an average of 36690 cubic feet per minute; shewing an increase from the use of the Jets of 9060 cubic feet. The bore of these Jets was about three-eighths of an inch.

Mr. Thomas John Taylor.—Were the Jets tried without the cylinders?

Mr. Dickenson.—No, Mr. Darlington was of opinion that without cylinders the result of the experiments would not be of any use.

The President.—Did you try any experiments with the Furnace and the Jets acting together?

Mr. Dickenson.—Yes with the Furnaces and Boiler Fires together we got in one case 36930 cubic feet per minute, and in another case 37990; being an average in the two cases of 37410 cubic feet per minute, or very little more than with the Jets. In that case the tubes obstructed the air-way very much, and one experiment gave with the Furnaces alone a decrease in the amount of ventilation as compared with the Jets, although the water-guage shewed an increase of from one and one-tenth to one and four-tenths. Thus, there was a diminished quantity of air with an increase of the water-guage; which shewed that there was an obstruction of the air at some point, or that there was a scale of air that must have been missed.

The President.—What was the amount of air which went through the cylinders? The experiments assume that all the air went through them.

Mr. Dickenson.—I am not sure upon that point. Mr. Wynne and Mr. Mackworth, I believe, have doubts upon it also. There were two small doors by the side of the Furnace, and I am not quite sure the air did not escape in that way. The area of these doors would be about eight square feet—each being about 2 feet by 2 feet. The Cylinders would be about a foot in diameter. The experiments made at the Cannel pits, as I said before, were not so satisfactory.

Mr. Wynne.—If those two doors were open there would only be about 15 feet area for the air to pass through into the Shaft. The Jets were placed across the Furnace drift, and there was a wall built to place the Jets in.

The President.—The fact would be that the air passing through the cylinders would be more obstructed than if the cylinders were not there.

Mr. Wynne.—Yes there would be full one-half of the drift taken up by the wall to inclose the cylinders.

Mr. Dickenson.—In the Cannel coal pits the Jets were placed in a different way; they were placed at one side, at an angle of about 15 degrees. The shaft was in bad order, and falling stones prevented the Jets from being placed in a vertical position. There were three splits of air, one split coming through the boiler fires. With the boiler fires we got 26·446 cubic feet per minute; with a temperature in the upcast of 115° and in the downcast of 48°; the water-guage being at nine-tenths. With the steam Jets and the boiler fires together at work, we got in one experiment 33531 cubic feet per minute, and in another experiment 35122 cubic feet. The temperature of the upcast had decreased down to 106°; but whether that was owing to the increased quantity of air going through or not I cannot tell—the temperature of the downcast remaining the same. The water-guage had increased to one and one-tenth. Taking the maximum, the result gives an increase of 8676 cubic feet per minute over the engine fires. With the Furnace and boiler fires together we got in one experiment 46354 cubic feet; and in another, 44805 cubic feet per minute; the temperature of the upcast having increased to 191°. The downcast was at 45°, and the water-guage had increased to 2 inches. The maximum increase by the addition of the Furnace was 19908 cubic feet per minute. Then we put the Jets, the Boiler fires, and the Furnace to work together; and whether owing to the Jets being placed in the way they were, or any other cause, the temperature diminished down to 140°, the ventilation fell off to 39060 cubic feet, and the water-guage to one inch and a half. Mr. Darlington did not consider that the Jets in these experiments were placed in the best position.

The President.—With respect to what Mr. Dickenson has said about Jets alone, and Jets in combination with cylinders, I may give you the results of the experiments which were made at Killingworth. The cylinders were placed at the bottom of the pit. With twenty-nine cylinders, each 6 feet long and 11 inches diameter, we made two experiments, in one of which, with a temperature of 104° we got 34314 cubic feet per minute; and in the other, with a temperature of 106° we got 35523 cubic feet per minute. This was with the cylinders on. Then the cylinders were taken off; and, in about one quarter of an hour, the same circumstances being kept up, the temperature in the shaft was 108°, and the quantity of air was exactly the same as with the cylinders on, namely, 35347 feet per minute. So that, in this case, there was certainly no increase of effect from the use of the cylinders. Notwithstanding, I will take care the experiments are properly carried out at Hetton, both with cylinders and without them.

Mr. Mackworth.—I, of course, take a deep interest in this question, and I have listened with great attention to the very excellent papers which have been read. Steam Jets were introduced into South Wales for the purpose of ventilation, in the year 1828. Since that time considerable advances have been made; and the principles of ventilation have formed the subject of an inquiry by a committee of the House of Lords. Mr. Vivian also instituted a series of experiments, the general result of which was condemnatory of the Jet. No experiments but those that were carefully made by practical and scientific men could prove satisfactory; and therefore I have been extremely happy to have had an opportunity of witnessing the experiments made by Mr. Wood. The subject is much more likely to be properly investigated in the hands of Colliery Viewers than in those of strangers to the practical working and operation of the mine below the surface; and until the system of Steam Jets has been shewn to be superior in effective ventilation to that in general use in the collieries of this district, I think the owners are right in adhering to the latter. I cannot express my satisfaction and gratitude at the liberality and generosity displayed by Mr. Wood, in undertaking the elaborate series of experiments upon which he is now engaged, and for his having repeated those experiments in the presence of other gentlemen interested in the investigation. At the same time I ought to express my thanks for the honour of being elected a member of this Institute. I am proud to think that I am associated with gentlemen

of such eminence in their profession—gentlemen distinguished alike for their scientific attainments and practical skill, for in no part of the world are such qualities so abundant as in this district. Now that the most eminent viewers have undertaken the investigation of this subject, we may be certain of arriving at a satisfactory result. When the experiments are fully carried out in the way suggested, it may be safely affirmed that no invention brought before the public previous to its being adopted, had given to it such a complete and satisfactory trial.

Mr. Wynne.—I would only say that I consider it a very high honour having been elected a member of this Institute. I beg to thank you ; and as I can say but little about the Ventilation of my own district to recommend it, the less I say the better. I will try to improve it.

The President.—I am sure we all feel highly indebted to these gentlemen for their presence this day, and we are also much obliged to them for the information they have given us. It may appear somewhat strange—the fact did not recur to my memory until I was reminded of it a short time ago—that the introduction of the Steam Jet in Wales, in the year 1828, was in a colliery which was at that time under my own management. A man of considerable ingenuity and natural genius, of the name of Stewart, who was sent by me from Killingworth, to take charge of the Colliery, made various experiments with the Jet, for the purpose of ventilating the mine, but the system was not then found to answer, and it was consequently abandoned.

The Meeting was then adjourned.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

EXPERIMENTS

ON THE

RELATIVE VALUE

OF THE

FURNACE AND THE STEAM JET,

IN THE

VENTILATION OF COAL MINES,

COMMUNICATED TO THE

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS,

ON MONDAY, 13TH DECEMBER, 1852,

AND FRIDAY, 4TH FEBRUARY, 1853.

BY

NICHOLAS WOOD, F.G.S.,

PRESIDENT OF THE SOCIETY.

Newcastle-upon-Tyne:

PRINTED BY M. & M. W. LAMBERT, 69, GREY STREET.

1853.

THE COMPARATIVE MERITS OF

FURNACE AND STEAM VENTILATION

IN COAL MINES.

The subject of the Ventilation of Coal Mines has recently taken a great hold of public attention. According to the statements of the Government Inspectors of Coal Mines, the number of individuals who have lost their lives by explosions in Coal Mines since November, 1850, amounted to the awful average of 250 persons annually.

The very statement of such a fearful fact sufficiently accounts for the excitement of the public,—justifies the enquiries which Parliament has thought proper at various times to institute, for the purpose of ascertaining if it is practicable to devise any means to obviate, alleviate, or prevent the occurrence of such dreadful calamities; and calls loudly upon all those who are interested, either in the management of Mines, in the success of Mining operations, or from feelings of humanity, to exert the utmost of their endeavours and means in the promotion of such measures as may most effectually accomplish so desirable an object.

It would, however, be misleading the public if it is expected that an improved mode, or any improved modes of Ventilation could alone accomplish such a *desideratum*, or could insure perfect safety. It might lead to a false security, the dependance on which alone might produce the the very evil which it is intended to remedy. Still the public have had it represented to them so assiduously,—so strongly,—and apparently, so conclusively, that most, if not all the explosions which occur are attributable to defective Ventilation; that the time has arrived when the whole question must be gone into, in such a manner as to present to the public some

conclusive data as to the causes of such accidents—the means which have been taken, or which are now in operation to afford security or safety; and also to investigate in a sound, practical, and scientific manner, whether any and what measures can be devised to prevent the recurrence of such lamentable calamaties.

I need not point out to my professional brethren, but I may be allowed to point out to those associated with us in promoting all that can in any way tend to the prevention of such accidents, and to the public in general; that the improvement of Ventilation, or increasing the ventilating powers of a Mine is only one of the many requisites in the practice of Coal Mining, which are necessary to ensure safety or security from explosions. There are a great many other operations, of almost, if not quite, of equal importance to a good Ventilation to be attended to, or carried into effect, to render a Mine even comparatively safe; and therefore the entire subject is a most complicated one, and one which requires the utmost care and caution in its investigation and adoption.

There is no doubt that all those other requisites have been well considered, and have become the subject of investigation, research, and practical adoption by individual members of the Institute, and we may hope that those researches, and the result of their practical experience, will be brought before the Institution in such a manner as that the united practical knowledge of the Institute will be made to bear upon their consideration and investigation, and that no exertions which are within the powers and capacity of the Institution will be wanting to arrive at measures which may best accomplish the object it is so desirable should be attained.

Without, however, depreciating the importance of the other requisites necessary to complete the security of a Coal Mine, it is no doubt a first and important step to attain as powerful a Ventilation as possible. And as I have already stated, so very important has this been considered by the public in general, and by almost all the non-professional writers on the subject, that an almost universal concurrence has been established, that the only *panacea* for the prevention of Accidents in Mines is Ventilation.

This has been much fostered by the results of the labors of the several Committees of the Houses of Lords and Commons, who have invariably laid great and predominant stress on better and complete Ven-

tilation of the Mines. And this feeling has been recently more intensely excited by the Report of the Committee of the House of Commons, which sat in the spring of 1852. That committee stated, in allusion to the labours of all those who preceded them [viz : to the several Reports of the Lords and Commons, to the Reports of the Inspectors and others,] that all their Reports leaned to the conclusion, that "increased Ventilation was the only true and secure means for the prevention of accidents." And the committee themselves state as their conclusion, "that a generally increased Ventilation is the truest security against explosions."

The committee further state as their opinion, "that any system of Ventilation depending on complicated machinery is unadvisable, since under any disarrangement or fracture of its parts, the Ventilation is stopped or becomes less efficient."

And this committee having received such evidence as appeared to them conclusive, reported as follows: "Your committee are unanimously of opinion that the Steam Jet is the most powerful, and at the same time, the least expensive method for the Ventilation of Mines." And, (after alluding to the destruction of life by the "After-damp," in cases of explosion) they add,—"Your committee are unanimously of opinion that the primary object should be to prevent the explosions themselves; and that if human means (as far as is known) can avail to prevent them, it is by the Steam Jet system as applied by Mr Forster: although even in such case it might be prudent in a Mine, especially fiery, to add an inexpensive Steam Jet apparatus at the top of the Downcast, as a means in reserve in case of explosion from neglect or otherwise."

Having been examined before that committee, and having given evidence, and expressed an opinion that the relative merits of the powers of the Furnace, and of the Steam Jet as producing Ventilation of Coal Mines had not been sufficiently tested; I stated to the committee that I was then engaged in making preparations for testing their comparative merits, and that it was my intention to institute a set of experiments to determine, if possible, their relative merits.

Considering that it was a proper subject of enquiry, or indeed, an enquiry incumbent upon some member of the profession, to conduct such a set of experiments as would, in a practical manner, determine the relative merits of what the committee call the "rival powers," and having made

such a pledge to the committee, I have at the Hetton, Killingworth, and Tyne Main Collieries, made a series of experiments to develope their relative powers, which I now have the honour to lay before the Institution.

I may here, however, premise, that it is not altogether a question of rivalry between Furnace power, and the power of the Steam Jet, the question extends itself to, whether the Steam Jet can be beneficially applied to the Ventilation of Coal Mines, either as a substitute for the Furnace—as an auxiliary to the Furnace—or, if it can in any way be adopted to prevent, or assist in preventing the recurrence of explosions in Coal Mines, or to render the mines more safe. It is in this point of view that I have placed the subject before me for investigation, and not as an advocate for, or opponent of, one system or the other; and I must leave to the institution and to the public in general, to determine, whether the investigation has been conducted in such a manner as to fairly, impartially, satisfactorily, and conclusively, test the relative merits of the two systems both separately, and in connection with each other, and whether I am justified in the conclusions to which I have arrived. I can only add, that if I have failed, it has not arisen from a want of inclination or determination to conduct the investigation impartially and conclusively, but from a want of ability to do so.

With these observations, I shall now proceed to lay before you the result of my investigation. In the first place, however, it is necessary to state that I found in the course of such investigation, and in the prosecution of the requisite experiments, that it was necessary, in order to test, in a practical manner, the relative merits of the two systems, to enter, in the first place, into the principles of each system in all their bearings; then to ascertain their relative practical effect of producing Ventilation in Mines. And to arrive at a satisfactory conclusion, I have found it also necessary to investigate and determine the resistance opposed to the moving power of each system in the practical operation of Mine Ventilation.

I shall, therefore, first of all, enter upon a short investigation of the principles and laws which govern the moving power of the Furnace, as a Ventilating force; next, a similar investigation of the principles, and moving power, and laws which govern the action of the Steam Jet. I shall then enter into an investigation of the laws which govern, and the amount of the various resistances opposed to such moving forces, and which it is requisite to overcome, in order to produce a certain standard of Ventilation.

I shall then give, in detail, the numerous experiments which I have found it necessary to make, in order to ascertain the practical effect of each system; and, lastly, determine the practical result and efficiency of each system, in the Ventilation of Coal Mines.

The experiments have been made on Mines almost as extensive as any in the kingdom, and in a manner, and of a magnitude, to test the practical effect of the two systems, as applied to Ventilation on a large scale. I have, however, found the subject branch off into so many ramifications which all required investigation, that I found my professional engagements would not allow me that time to pursue them, to such an extent, at least, as I could have wished. I shall, however, take the liberty of presenting to you what I have done, and which I trust will not be found without interest, if not conclusive on the subject. Other gentlemen, I find, are also engaged in similar investigations, and are making experiments in other collieries, on the comparative merits of the two systems, which will also be laid before the Institution.

When all these, and probably others which may arise out of the further investigation of this important subject shall have been laid before you, I trust that the Institute will be possessed of a mass of information on a subject of enquiry of infinite importance to the mining interest of the district, and, indeed, to the nation at large; out of which we may trust that something may be elicited, which may alleviate, if not avert some of those dreadful calamities which have so often produced such distress in the coal mining districts of the kingdom.

With these further observations, I shall now proceed to the investigation of the principles and powers of the Furnace, as a means of producing Ventilation of Coal Mines.

DESCRIPTION OF FURNACES USED IN VENTILATION.

The period when the Furnace was first used as a means of Ventilation of Coal Mines, cannot be correctly traced. It is stated that Mr. Niewald, of Sweden, in the year 1740, and Mr. Jars, in 1760, both endeavoured to elucidate the art of Ventilating of Mines. The latter laying down principles and explaining Natural Ventilation, [which it is said was

then little understood,] and suggested a small Furnace at the top of the pit, with a chimney to aid the natural Ventilation.

This appears to have been the first mode adopted of producing artificial Ventilation. The top of the upcast shaft was closed up, a chimney, hollow shaft, or tube, (as it was called,) was built at a little distance from the pit, to a height, varying from 30 to 60 feet or upwards, according as a more or less powerful Ventilation was required, with a covered passage between the top of the pit and the bottom of the tube. A large fire or furnace was placed in this drift or passage near the bottom of the tube, —the rarifying power of which, together with the effect of the heated air in the shaft, produced the Ventilation. A side drift, or covered passage was also required for the purpose of obtaining access to the Furnace; and into which were placed two doors, so that in passing to the Furnace one of these should be constantly shut, in order to prevent the intrusion of the outer air, to the heated air of the shaft.

Fig. 1, Plate I. represents a sketch of this mode of Furnace Ventilation. *A* the pit or shaft, *B* the covered way or drift, *C* the chimney or tube, and *F* the fire or Furnace.

This description of Furnace appears to have been used for a long period, as we find at some of the old collieries, remains of the chimneys standing to this day. The last used in the neighbourhood of Newcastle was at the Felling colliery, and which was in use when an explosion took place on the 26th May, 1812, by which 92 men and boys were killed.

It will be observed that this mode of Ventilation could only be used where the upcast shaft was closed up, thus rendering it inapplicable for the drawing of coals.

This mode gave way to the application of the fire or Furnace being placed at the bottom, or near the bottom of the upcast shaft, which, operating on the air in the entire length of the shaft, was so much the more efficient, as the depth of the shaft was greater than the height of the chimney or tube.

Figs. 3, 4, 5, 6, and 7, Plate I., represent modern Furnaces, being a representation of the Furnaces of Hetton colliery, where the experiments

hereinafter described were made, and which will be more particularly described when the experiments are given.

This description of Furnace or Furnaces are generally placed at a distance of 30 or 40 yards from the bottom of the pit, so that the flashes of flame, when fresh coals are put on, should not reach the shaft, or that the flame should be distributed, or mixed with the air, before it reaches the shaft. The drift for the passage of the air from the Furnace to the shaft is always, especially in deep shafts, made to rise at an angle of 30 to 45 degrees. In more shallow shafts, it may be more advisable, if it can be done, to place the Furnace as near the bottom of the shaft as possible, so that the greatest length of column of heated air should be obtained.

The above may be taken as the general form of Furnace used in Furnace Ventilation, they may be varied in width, the form of the arch, and in some other respects, but the mode in which the Furnace is made to operate is in all the same, viz., to pass the air of the mine over the fire, and so to raise it to as high a temperature as possible.

PRINCIPLES OF ACTION OF THE FURNACE.

The mode of application of the Furnace is therefore very apparent, but as I shall have, in order to compare its relative merits with the Steam Jet, to go very minutely into, not only its principle of action, but its practical effect in producing Ventilation, it will be requisite that I should explain in detail the manner in which the Furnace acts in the production of a current of air around the workings of a Coal Mine.

Supposing two shafts *A* and *B* Fig. 2, Plate I., of equal depth, with a communication between them at the bottom, by a drift or passage *C*. If these two shafts, and the drift *C* were filled with air of precisely the same temperature and density, the air would remain stagnant, there would be no current. But, suppose by any means heat is imparted to the air in one of them, say in *B*, then the equilibrum will be destroyed; the effect of the heat in *B* will be to expand the air in that shaft, to render it specifically lighter than the column in *A*, and consequently if there is an open passage at *C*, the heavier column of *A* pressing upon the lighter column of *B* will force it upwards, and produce a current of air along the passage *C*, in the direction of the arrow.

And, if the heat imparted to the air in the shaft *B* be continuously kept up, by, for instance a fire or Furnace placed at *F*, over which the air from *A* should pass, then a continuous current of air will be kept up; down the downcast *A*, along the passage *C*, and up the upcast *B*.

And, if we suppose, instead of the drift or passage *C* being a drift simply between the bottom of the two shafts, that it is extended so as to form a variety of drifts; or in fact, to comprise the workings of a colliery, then we have an illustration, or representation of the whole action of the Furnace in producing the ventilation of a coal mine.

This, then, is the entire principle of action of "Furnace Ventilation," a fire or Furnace, or in some cases two or three Furnaces, are placed at, or near the bottom of the upcast shaft, over which the air that passes down the downcast shaft, and around the workings is conveyed; and which being heated by such Furnace, or Furnaces, passes into the upcast shaft, and thus constitutes a column of air of less density than the column in the downcast shaft; and the column of heavy air in the downcast pressing, through the medium of the column of air around the workings, upon the lighter column of the upcast, so produces a continuous current of air through the mine of greater or less velocity, as the column of air in the shaft *B* is of less or greater specific weight than the column of air in the shaft *A*.

It is the same thing, and is, I dare say, a more popular definition to say, that the heat of the Furnace *F* acting upon the air passing over it into the shaft *B*, renders such air specifically lighter; and that the tendency in columns of air heated, above that with which it is in contact, to rise, creates an upward current of air in the shaft *B*; and that the current of more dense air passing to the Furnace rushes in to fill the vacuum, which would otherwise be created by the upward motion of the heated air, and thus a continuous current is produced around the workings, and down the shaft *A*. Whatever language, however, we make use of to describe the mode of action, it is quite clear that the motion of the current of air around the workings is produced by the difference of weight between the two columns *A* and *B*; and, that in the ratio in which we increase this disparity, or make the one heavier than the other, so much the more power do we obtain to produce Ventilation.

Before proceeding further into the principles of Furnace Ventilation, it may be useful to allude to Natural Ventilation, as it bears to

an important extent, in some cases, upon the subject of our investigations. It is well known, that as we descend into the earth by a shaft or pit, the temperature increases, and it increases in some ratio with the depth, and many experiments have been made in deep mines to determine the rate of increase. We also know that the superficies of a mine in which workings have been made also give out heat, and that the air, after it has passed through a mine, is of a higher temperature than when it entered. Such heat acting upon the air of the mine rarifies it, and passing into the upcast shaft, presents a column of air specifically lighter than that in the downcast shaft, and thus a continual current of air is produced, down the downcast, around the workings, and up the upcast shaft, without the aid of artificial heat, or of a Furnace, and this constitutes what is correctly called NATURAL VENTILATION.

NATURAL VENTILATION.

I shall give two cases of this kind which have come under my observation, and which it may be useful to communicate; the first, a case where the workings were very limited, and the other, where the workings were more extensive. The first is that of the deep winning at Seaton, near Seaham. The shaft is 260 fathoms, or 1,560 feet in depth to the Hutton Seam.

The shaft is 14 feet in diameter, with an air-tight brattice dividing it into two equal divisions from the top to the bottom. After the pit had been sunk, and a communication in the coal made around the walls or pillars left for the support of the shaft, the pit was not worked for upwards of two years, and during that time, only two men were in the mine for about 8 hours in each day. There was, therefore, no artificial heat, especially when the men were out of the pit. I made an experiment at this pit, the details of which are given in the following Table, No. 1, by which it will be seen that a quantity of heat evolved in the drift, along which the air passed, raised the temperature of a current of air of 7,000 cubic feet per minute $3\frac{1}{2}°$. The distance which the current of air traversed from the bottom of the downcast to the bottom of the upcast was 3,036 feet. The superficies of surface to which such air was exposed, and

which gave out the heat cannot be correctly ascertained from the irregularities in the area of the passages, but it may be taken at about an average of 20 feet in each foot of drift, or in the aggregate of 60,720 square feet.

TABLE No. I.

Experiments made at the Seaton Pit on Natural Ventilation, depth of pit 260 fathoms, or 1,560 feet. Diameter of pit 14 feet, divided equally by a timber brattice, air tight, from top to bottom.

	Depth from top of Pit.	Temperature.		Difference of Temperature.	
		Downcast.	Upcast.		
	Feet.	Degs. Far.	Degs. Far.	Degs. Far.	
	Bank.	44°	46°	2°	
	120	44	47·5	3·5	
	240	43·75	48°	4·25	
	360	44·25	48	3·75	
	480	44·25	48	3·75	
	600	44·75	48·25	3·5	
	720	45·25	49	3·75	
	840	45·25	49	3·75	
	960	45·5	49	3·5	
	1,080	46·5	49·25	2·75	
	1,200	47·75	51	3·25	
	1,320	48·5	51·75	3·25	
	1,440	49·	52	3·	
	1,560	49·5	62·5	3·	
	Average.	46°	49°·5	3°·5	

Quantity of air, 7,002 cubic feet per minute. Length of air courses, 3,036 feet, the air being split on each side of the shaft. Average area of air courses, 24 square feet, with some small contractions.

The next case of Natural Ventilation is shewn in the experiments at Tyne Main Colliery. To obtain as accurately as possible the power of the Steam Jet apart from the aid of any artificial Ventilation, the Furnaces were put out, and they were kept out until the temperature of air in the upcast shaft was precisely the same as that of the air entering the bottom of the shaft, after passing through the mine.

On referring to Tables XV. and XVI. it will be seen that in both the experiments on the 14th and 15th January respectively, the temperature in the return air, or air passing to the bottom of the upcast shaft, after having passed through all the workings, was 63°, and that in the upcast shaft at 10 fathoms from the surface, the temperature was 62° in the first, and 63°, 64°, 65°, in the second experiment. The temperature of the air at the bottom of the downcast, or before entering the workings, was, in the former case, 42°, and in the latter, 43°, so that the heat communicated to the air in its passage through the workings of the mine was respectively 20° and 21°, upon a quantity of air equal to upwards of 36,000 cubic feet per minute.

The following Table will shew the results of these experiments.

TABLE No. II.

Date of Experiment.	Depth of Shaft in feet.	Temperatures.					Quantity of Air in cubic feet per minute.
		Bank.	Bottom of downcast.	Return Air.	From surface in upcast Shaft.		
					60 feet.	390 feet.	
1853.							
Jan. 14th ...	672	36°	42°	63°	62°	61°	34·955
„ 15th ...	„	43°	45°	63°	64°	62°	36·564
„ „ ...	„	43°	45°	63°	65°	61°	37·182

It is extremely difficult to ascertain the precise extent of the superficies which produced the above result. The entire workings of the colliery embrace an extent of about 288 acres. In about 50 acres, the whole of the coal is exhausted, and comprises what is called goaf; the current of air only sweeping around its edges, and receiving in its passage the heat emanating from the goaf. The remainder of the workings has been worked in the pillar and stall method, the excavated portion comprising about 56 acres, the remainder, 102 acres, comprising the coal left. There is, therefore, excavated, 106 acres, and standing in pillars, 102 acres, each pillar being generally about 30 yards by 11 yards, and the seam is 5 feet 6 inches in height on the average.

The heat thus given out and communicated to the air in its passage through a coal mine is necessary to be taken into account in this in-

vestigation; as of itself it produces ventilation of a certain amount, independently of any artificial means, but which it certainly materially assists. The quantity of heat evolved in so small an extent of workings, as that of the first experiment, we find to be considerable, and, in that of the second, very much more so. In mines of greater extent it is, of course, still greater, in proportion indeed to the extent; and when we also take into consideration the heat produced by the number of men, boys, horses, and ponies, and by the gases given out in an extensive pit, we shall find that this amount of heat is considerable, and that it has a material effect in aiding artificial ventilation, especially in deep mines.

It is, however, necessary to state, that this result arises only when the temperature of the atmosphere is very low, and when, consequently, the temperature of the air entering the workings of the mine is also very low; in summer the result is different. We find from experience, that the temperature of the return air, after it has passed through all the workings of the mine, is nearly the same in summer and winter, though the temperature of the air entering the workings varies more than 20°; absorbing almost, if not quite the whole of the temperature producing "Natural Ventilation." In winter, therefore, we have the assistance of, say 20°, to assist the Artificial Ventilating Power of the mine, and in summer nothing at all; and so in proportion as the temperature of the atmosphere varies.

We are thus enabled to account for the sluggish ventilation of the mines in hot and sultry weather, and this also shows the necessity at such periods of increasing the Artificial Ventilating Powers of the mines. The increased power required as exhibited, in the above case, is that of heating 36,000 cubic feet of air 20°, or 720,000 cubit feet of air 1° per minute. In Furnace Power we find by the experiment, Table XII., that 1lb. of Coal consumed per minute, heated 11,066 cubic feet per minute of air 62°, or 686,092 cubic feet 1°; we therefore require about 1lb. of Coal per minute extra to compensate for the loss of Natural Ventilation, when the temperature of the air in the downcast, and in the return from the workings, is the same. But in the case of the Steam Jet we find the increase over the Natural Ventilation only about 12,500 cubic feet per minute, little more than one-third of the amount of Natural Ventilation; though such a result was produced by the evaporation of 1·82 cubic feet of water per minute into steam of 40lbs. pressure per square inch and applied at the top of the Pit in 61 Jets $\frac{5}{16}$ths of an inch in diameter.

Before entering upon the ventilating powers of the Furnace, I may also premise, that I have, in the course of my investigations, endeavoured to conduct them in as purely a practical manner as possible, so that the results should exhibit the practical working effect of the two systems, on collieries of sufficient magnitude to set the matter at rest, or leave no doubt upon the subject, I have, therefore, abstained from theoretical disquisitions almost entirely; only so far certainly, as I have found it necessary to elucidate the subject, and assist in arriving at a correct conclusion.

I shall now, endeavour to determine and lay down some practical data of the power of the Furnace in producing Ventilation.

We have seen that the power of the Furnace consists in the difference of density of the two shafts, the downcast *A*, and the upcast *B*. If the temperature of *A* is known, then we can correctly ascertain the weight of its column, the depth being known; and in the same manner the temperature and depth of *B* being also known, we can ascertain the weight of its column, and we can take the weight of each in lbs. avoirdupois per square foot of area of the shaft.

I have adopted this mode of investigating the powers of the Furnace, in lbs. pressure per square foot of area of shaft, as I shall in like manner investigate the powers of the Steam Jet in lbs. pressure per square foot of area; and having done so in both cases, I shall then, from the same data, determine their relative practical effect.

Reverting back to the Furnace, having the weight of the column *A*, and the weight of the column *B*, then the power to produce motion is well known, being the same as that of two weights of different magnitudes, viz., of the weight *A* [represented by the weight in lbs. of the column *A*], and the weight *B* [represented by the weight in lbs. of the column *B*], passing over a pulley. The theoretic expression of which is well known. The weight *A*, being the moving power, and the weight *B*, being the resistance opposed to the free motion of *A*. Friction, resistance of the opposing medium of air, &c., being set aside in the theoretic investigation of the effect of two such forces. We may, however, include these, even in the theoretic consideration of the subject. We can represent the friction, resistance of the air, and any other opposing medium, by an additional weight *C*, to be added to *B*; and hence we have A = the moving power, and $B + C$ = the resistance. And then, by the well-known principles of dynamics, having the laws which govern the weight and motion of *B* and *C*, we can determine the expression of power requisite to produce a given effect.

It is precisely in this way I propose to deal with the practical investigation of the Furnace and Steam Jet. I take the weight of the column of air in the downcast shaft A in lbs. per square foot of area of the shaft or pit, as the moving power of the furnace; and in like manner, the force or pressure per square foot of area of the shaft, as the moving power A' of the Steam Jet. Then I take the weight of the column B of the upcast as one part of the resistance, and the friction resistance, or drag of the air in its passage around the workings of the mine, as the other part of C; being together the resistances opposed to the power A of the Furnace, in the one case, and to the power A' of the Jet in the other.

If the respective values of A A' and B C were known, we could have determined theoretically the merits of the two systems without having recourse to expensive and tedious experiments; but it is precisely that we have not those values, and that we cannot obtain the practical operative effect of them, without a series of experiments, on a sufficiently extensive scale and magnitude, to obtain correct practical data of their values; that the matter has remained so long in doubt, and that I have found it necessary to pursue the subject so minutely, and to carry out such extensive experiments.

I trust, however, that the experiments which I shall lay before you will not only determine the requisite data; but that they will furnish data going far towards establishing practical results in other branches of Coal Mine Ventilation.

I shall now therefore proceed, in the first place, to determine the power A and the resistance B of Furnace Ventilation, which we find represented by the weight of the air of the two columns A and B. These, of course, are determined by the ascertained weight of air at the different degrees of temperature in the respective shafts.

The weight of air at different degrees of temperature, as determined by Dr. Dalton and Gay Lussac, was long considered as correct. They found that atmospheric air, the barometer being at 30 inches of mercury, expanded $\frac{1}{480}$th part of its volume, for each degree of temperature (Fahrenheit) from 32° upwards, or $\frac{1}{448}$th from unity.

The more recent and extensive experiments of Magnus and Regnault has, however, determined the rate of expansion to be the $\frac{1}{491}$th part, from

32°, or the $\frac{1}{459}$th part from unity. And they found, which is of great importance in this investigation, (as indeed did Dr. Dalton also,) that the degree of expansion was in the direct ratio of the degree of heat imparted.

The volume at 1° being 459, the volume at any other temperature, t, will be $459 + t$. Hence, to find the volume of any column of air at any given degree of temperature, we have only to take the volume at unity at 459, and add the number of degrees of temperature of any column of air, the sum will be the volume of that column of air. Thus, the volume at 60° will be $459 + 60 = 519$, and the volume at 180° will be $459 + 180 = 639$. Therefore, if the air in the columns A and B are respectively 60° and 180°, then the volume of the columns will be respectively 519 and 639.

Dr. Dalton has given a Table of the expansion of air, from 32° to 212° of which the following is a copy.

Table of the Expansion of Air by Heat, by Dr. Dalton.

Fahr.	Volume.	Fahr.	Volume.
32°	1,000	130°	1,215
40	1,021	140	1,235
50	1,043	150	1,255
60	1,066	160	1,275
70	1,089	170	1,295
80	1,110	180	1,315
90	1,132	190	1,334
100	1,152	200	1,354
110	1,173	210	1,372
120	1,194	212	1,376

And the volume for any other temperature, t, will be $1000 \times \frac{448 + 32^{\circ}}{448 + t.}$

Professor Hann, in his evidence before the Committee of the House of Commons, 1852, says, "the experimental results of Magnus and Regnault, consider the expansion of air in being heated from t to t' as $1 - \frac{459 + t}{459 + t'}$ expressed in volume t, the original volume being taken as unity."

This expression makes the degree of expansion in the direct ratio of the temperature, and the following Table will show the expansion of air at the different degrees of temperature.

Table of the Expansion of Air by Heat, by Magnus and Regnault.

Fahr.	Volume.	Fahr.	Volume.
32°	10,000	130°	11,996
40	10,416	140	12,199
50	10,366	150	12,403
60	10,570	160	12,606
70	10,773	170	12,810
80	10,977	180	13,014
90	11,181	190	13,218
100	11,385	200	13,421
110	11,588	210	13,625
120	11,792	212	13,666

And the volume of any other temperature, t, will be $1000 + \frac{459 + 32^{\circ}}{459 + t}$.

The difference between the two Tables, it will be seen, is not of much consequence, in a practical point of view; but they both shew, what is very important in the matter under consideration, that the expansion of air is in the direct ratio of the degree of heat imparted to it. And Mr. Tredgold, in his work on Warming and Ventilating Buildings, adopts the same result He says, p. 26, "If you would ascertain the quantity of fuel that would heat a cubic foot of air 1°, then the specific heat of water being 1, that of an equal bulk of air is 0·00035, or $\frac{1}{2850}$ (see Art. 217, Table II.); and if the quantity of fuel that will heat a cubic foot of water 1° be multiplied by 0·00035, the product will be the quantity of fuel that will heat a cubic foot of air 1°, and 20 times that quantity will heat it 20°, 30 times will heat 30°, and so on for any other temperature."

I shall now ascertain the relative weights of the two columns *A* and *B*. Mr. Tredgold, in the work above alluded to, assumes the weight of a cubic foot of air at the temperature of 60°, barometer 30 inches, at 527 grains Troy, taken from Dr. Thompson's Specific Gravity of Gases, System of Chemistry, Vol. III. But the more recent experiments of Dr. Prout makes the weight of 100 cubic inches 31·0117 grains, at the same temperature and barometrical pressure.

As Professor Hann has adopted this latter standard, I shall do the same, and consequently we have only to find the number of cubic inches of air in any shaft, and the temperature; and we have the weight in grains Troy in any column of air. The weight of air being, as above stated, inversely as its bulk.

As it will, however, be more convenient in our further investigations, to take as a standard, the weight or pressure in lbs. Avoirdupois for each foot of surface, it is easy to convert Troy into Avoirdupois weight. We have, therefore, 31·0117 × 1728 ÷ 7000 × 100 = ·096376lbs. Avoirdupois, as the weight of a cubic foot of air at 60°, and 30 inches barometric pressure. And the following Table will shew the weight of different columns of air in lbs. Avoirdupois, at different degrees of temperature, in shafts of different depths.

326 cubic inches equal 1 lb Avoirdupois weight

TABLE III.

Table of the Pressure of the Air in lbs. *Avoirdupois per Square Foot of Surface or Area, of Shafts of different Depths, and subjected to different Degrees of Temperature.*

Temperature.	Depth of Shafts, in Feet.																	
	120	180	240	300	360	420	480	540	600	660	720	780	840	900	960	1,020	1,080	1,140	1,200
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
32°	9·710	14·565	19·421	24·276	29·131	33·986	38·842	43·697	48·552	53·407	58·262	63·118	67·973	72·828	77·683	82·538	87·394	92·249	97·104
40	9·555	14·332	19·109	23·887	28·664	33·442	38·219	42·996	47·774	52·551	57·328	62·106	66·883	71·661	76·438	81·215	85·993	90·770	95·548
50	9·367	14·051	18·734	23·417	28·101	32·784	37·468	42·152	46·835	51·519	56·202	60·886	65·569	70·252	74·936	79·620	84·303	88·987	93·670
60	9·187	13·780	18·373	22·966	27·560	32·153	36·746	41·339	45·933	50·526	55·119	59·712	64·306	68·899	73·492	78·085	82·679	87·272	91·865
70	9·013	13·519	18·026	22·532	27·039	31·545	36·051	40·558	45·064	49·571	54·077	58·584	63·090	67·597	72·103	76·609	81·116	85·622	90·129
80	8·846	13·268	17·691	22·114	26·537	30·960	35·383	39·806	44·228	48·651	53·074	57·497	61·920	66·343	70·765	75·188	79·611	84·034	88·457
90	8·684	13·027	17·369	21·711	26·054	30·396	34·738	39·080	43·423	47·765	52·107	56·449	60·792	65·134	69 476	73·818	78·161	82 503	86·845
100	8·529	12·794	17·058	21·323	25·587	29·852	34·117	38·381	42·646	46·911	51·175	55·440	59·704	63·969	68 233	72·498	76·763	81·027	85·292
110	8·379	12·569	16·758	20·948	25·138	29·327	33·517	37·707	41·896	46·086	50·276	54·465	58·655	62·845	67·034	71·224	75·414	79·603	83·793
120	8·235	12·352	16·469	20·586	24·704	28·821	32·938	37 055	41·173	45·290	49 407	53·525	57·642	61·759	65·877	69·994	74·111	78·228	82·346
130	8 095	12·142	16·189	20·237	24·284	28·332	32·379	36·426	40·474	44·521	48·569	52·616	56·663	60·711	64·758	68·805	72·853	76·900	80·948
140	7·959	11·939	15·919	19·899	23·879	27·859	31·838	35·818	39·798	43·778	47·758	51·738	55·717	59·697	63·677	67·657	71·637	75·616	79·596
150	7·829	11·743	15·658	19·572	23·487	27·401	31·316	35·230	39·145	43·059	46·973	50·888	54·802	58·717	62·631	66·546	70·460	74·375	78·289
160	7·702	11·554	15·405	19·256	23·107	26·958	30·810	34·661	38·512	42·363	46·215	50·066	53·917	57·768	61·619	65·471	69·322	73·173	77·024
170	7·580	11·370	15·160	18·950	22·740	26·530	30·320	34·110	37·900	41·690	45·480	49·270	53·060	56·850	60·640	64·430	68·220	72·010	75·800
180	7·461	11·192	14·923	18·653	22·384	26·115	29·845	33·576	37·307	41·037	44·768	48·499	52·229	55·960	59·690	63·421	67·152	70·882	74·614
190	7·346	11·020	14·693	18·366	22·039	25·712	29·386	33·059	36·732	40·405	44·078	47·752	51·425	55·098	58·771	62·444	66·117	69·791	73·464
200	7·235	10·852	14·470	18·087	21·705	25·322	28·940	32·557	36·175	39·792	43·410	47·027	50·644	54·262	57·879	61·497	65·114	68·732	72·349
210	7·127	10·690	14·253	17·817	21·380	24·944	28·507	32 070	35·634	39·197	42·761	46·324	49·887	53·451	57·014	60·577	64·141	67·704	71·268
212	7·106	10·658	14·211	17·764	21·317	24·869	28·422	31·975	35·527	39·080	42·633	46·186	49·739	53·291	56·844	60·397	63·949	67·503	71·055

The foregoing Table shews the pressure per square foot of area of the shaft, but the amount of ventilating power depends upon the area of the shaft,—a shaft of 100 feet area, being double the power of that of a shaft of 50 feet area, and a shaft of 150 feet area, treble that of a shaft of 50 feet area. Having the mean temperatures of the upcast and downcast shafts, we have only to multiply the difference between the respective pressures per square foot of the two shafts, as shewn in the preceeding Table, by the area of the shaft, to ascertain the total amount of power, in lbs. Avoirdupois, of any shaft. And if we require that to be expressed by horses' power, we have only to multiply that, by the velocity of the air in feet per minute, and divide the sum by 33,000 feet, and we have the number of horses' power of ventilating force.

The above Table likewise shews the weight or pressure per square foot of area of shafts of different depths and different degrees of temperature, and enables us to ascertain the motive power A in shafts of the depths shewn in the Table, when the mean temperature of the air in the downcast shaft is given. And it also shews the resistance or weight B of the air in the upcast shaft, opposed to the motion or moving power A of the air in the downcast, when the mean temperature of the air in the upcast is given.

Thus, suppose the mean temperature of air in a downcast pit 900 feet in depth to be 50°, then the motive power A is 70·252lbs. per square foot of area of shaft. And if the mean temperature of the upcast B be 180°, then the resistance B of the weight of the column is 55·96lbs. per square foot of area. Consequently, the difference, 21·262lbs. per square foot of area of shaft, represents the power applicable to overcome the resistance or drag of the air of the mine, C; and produce a current of air which will fill up, or produce the dynamical equilibrium of the system, and which we have denoted by C. 14·292

We shall afterwards go into an investigation of the amount, and principles which govern the resistance or variety of resistances, which represent C, and this we shall find to be the most difficult part of the undertaking, comprising, as it does, all the complication of the obstructions opposed to the moving or ventilating power of the mine, whether that power be the Furnace, or the Steam Jet. Previously, however, to entering upon this part of the subject, it is requisite to notice a qualification in the power of the Furnace in the Ventilation of mines, which was raised during

the investigation before the Committee of the House of Commons, in 1852, and which has been termed the "Furnace limit."

It is rather inexplicable how this outcry should have been raised as against the Furnace, without applying the same limit to the Steam Jet; as in the list of definitions and technical explanations in the Report of the Committee, the principles of action of the Furnace, and the resistance or drag of the air are correctly stated, except only as regards the "Vena contracta," which is scarcely separable from the drag or resistance of the air.

It is there stated, as has been denonstrated by the preceeding enquiries, that the power of the Furnace is in the direct ratio, or arithmetical ratio, of the heat employed; no limit is pretended to be assigned to this power. Professor Hann himself gives the expansion of air, and consequently the power of the Furnace as equal to $1 - \frac{459 + t}{459 + t'}$ t being the temperature of the downcast, and t' the temperature of the upcast,—no limit is there given; and the experiments of Magnus and Regnault, though carried beyond the temperature practically in use in Coal Mine Ventilation, shewed that the ratio of the expansion of the air, and consequently the power of the Furnace, was in the direct ratio of the increase of temperature.

It is true, as stated by Professor Hann, and adopted in the Report, that the resistance or drag of the air increases in a geometrical ratio, and that consequently there is, if not a theoretical, a practical limit to the ventilating power. But it ought to have been stated, that this limit was equally applicable to whatever power was employed, unless that power increased, or is made to increase, in any other than a direct or arithmetical ratio; that it was equally applicable to the Steam Jet and the Furnace; and that, in fact, it is the resistance, and not the power, which presents a practical limit to the amount of Ventilation; and that it operates, as will hereafter be shown, to produce a practical limit to the power of the Steam Jet, as well as to that of the Furnace.

STEAM JET.

The Steam Jet was first proposed as a ventilating power by Mr. Goldsworthy Gurney, in 1835, to a "Committee of the House of Commons on Accidents in Coal Mines."

His proposition to the Committee was, "a common boiler, furnished with a small tube, leading to the shaft, and pointing either up or down, as you desire the current to be driven, placed in a cylinder, the size of which must be governed by the quantity of steam used, or the quantity of current you intend to make. A very small Jet of Steam, at 60lbs. to the inch, of about the size of a goose quill, will dislodge 350,000 cubic feet of air in an hour."

Again, in 1839, Mr. Gurney proposed to the South Shields Committee, Steam Jets as a ventilating power, and sent drawings of the mode of applying the Jets, which may be seen in their Transactions. Mr. Gurney then proposed that the boiler should be placed at the top of the pit, and the Jets placed within it, about 20 or 30 feet down. And he says, "16 Jets of $\frac{5}{16}$ths area, fed by steam of 40lbs. per square inch, placed not less than 30 feet deep in the upcast, and equally divided through its sectional area, would produce a current of air, at the rate of 20 miles per hour, in a shaft 41 feet area, or 72,160 cubic feet per minute."

In 1849, Mr. Gurney again brought forward, before a Committee of the House of Lords, the Steam Jet; and lastly, in 1852, before a Committee of the House of Commons. With regard to the mode of applying the Jet, Mr. Gurney, in answer to Question 433, Lords' Committee, 1849, "Is it desirable to place them near the surface, or near the bottom?" said, "Save the rarefaction, and the little power given out by the heat of the Steam, in the shape of heat, and lightening the column, it does not matter where it is placed: it is not worth consideration." And in answer to Question 434, says, "it is not worth calculation." And he mentions an experiment at Seaton Delaval, making the quantity of air due to the rarefaction of the steam only 6000 cubic feet per minute, the quantity of the Steam Jet being 33,000. He therefore assumes the ratio to be as 6 is to 33.

Notwithstanding the very flattering estimate of the powers of the Steam Jet, it does not appear that it was used at any of the collieries in this district, until Mr. Forster adopted it, at the Seaton Delaval colliery, in 1849, and, since then, it has been tried in some other collieries.

It has always appeared to me, that great part of the difference of opinion which has arisen as to the utility and efficiency of the Steam Jet, has been occasioned from a clear distinction not having been made between the effect arising from the rarefaction of the air in the upcast shaft, by the

heat of the engine fires, and by the heat given out by the steam (when the boilers are placed at the bottom of the pit); and the mechanical effect, or propulsive power, of the Steam Jet, as a moving force, in producing Ventilation. It is true, Mr. Gurney attributes little or no effect to these aids, which, as previously noticed, he says are "not worth consideration," but attributes almost the entire power to the Steam Jet, as a propulsive force.

We shall not, however, be able thoroughly to estimate the power and efficiency of the Steam Jet, unless we separate, and determine by experiment, or in some other conclusive manner, what is due to each of the mechanical forces, which contribute to form the entire power of the Jet as a means of Ventilation, in the different modes in which it has been or may be applied.

In order to accomplish these we shall have to consider separately, and subject to experiment,

1st.—The effect of the Engine Fires as regards rarefaction in the upcast shaft, when the boilers and Jets are placed at the bottom of the pit.

2nd.—The effect of the rarefaction, and of the column of steam in the upcast shaft, when the Jets are placed at the bottom of the pit, whether the steam is obtained from boilers at the bottom of the pit, or is conveyed by pipes from boilers placed on the surface.

3rd.—The mechanical effect of the Jets alone as a propulsive force, to produce Ventilation.

In the consideration of the first of these, little explanation is required. If a fire is employed to pass underneath and around a boiler, to convert water into steam, (apart from the consideration of the effect of that portion of the heat communicated to the steam, and again given out in its passage up the shaft, which comes under the second head of the enquiries,) the surplus heat, passing into the shaft, acts upon the air in the upcast shaft in precisely the same manner, so far as regards the quantity of heat so communicated, as if such heat proceeded from a Furnace, viz., by rarefying the air in the shaft, and producing an amount of Ventilation corresponding with the quantity of heat so passing off.

It is, however, worthy of remark, and it is a circumstance of some importance in this enquiry, that a considerable diminution of effect is sustained, if such fires are of the ordinary description ; the combustion of the coal in the engine fires is not near so perfect as when the coal is consumed by a Furnace. In the former case, the air is made to pass entirely through the grate bars, and through the fire, driving off a good deal of the volatile and combustible matter of the fire unconsumed : whereas in the Furnace, the air passes over the fire with great velocity, and the combustible matter is thus again thrown upon the fire, and is almost entirely consumed. Indeed, in a well-worked Furnace, the combustion is almost perfect.

This is well known to the Profession, in upcast shafts, with engine fires at the bottom, volumes of smoke are almost continually issuing ; whereas in Furnace Ventilation alone, there is little or no smoke emitted. This is not a simple question of comparative consumption of coal to produce the same effect, as the smoke from the engine fires adds to the weight of the column of air in the shaft, and so tends also to diminish the effect of the rarefaction. The experiments which will hereafter be given, will prove this in a very conclusive manner.

In the consideration of the second set of enquiries, that of the effect of the steam passing up the shaft also requires consideration. It operates first of all in increasing the temperature, and, by the rarefaction of such heat, adds to the ventilating power. We have likewise to take into consideration the weight of the column of steam, compared with the weight of a column of air of the same temperature. And we have to take into consideration that property of steam and air, in contact with each other, to combine mechanically, and present a united bulk different from that of the simple addition of the two volumes. I have however, previously stated that it was my intention, in this paper, to deal with this investigation in a purely practical manner. I shall therefore simply confine myself to a statement of the theoretical result of the above questions, as deduced by the most modern enquirers, without going more into detail than is absolutely necesssary to illustrate the subject.

The effect of the heat of the steam upon the column of air in the shaft, will be the same as that of a similar quantity of heat communicated in any other way, except only as modified by the weight of the column of steam, in the first instance, and still further modified by the properties of air and steam when mixed.

According to the specific gravity of steam, as given by Dr. Thompson, it appears that a cubic foot of steam at 60° weighs 329·4 grains, when the barometrical pressure is 30 inches, and if f be any other pressure we have—as $30 : f :: \frac{329{\cdot}4\,f}{30} = 10{\cdot}98\,f$ = the weight of a cubic foot of steam, at the force f, and temperature of 60°. Let t be the temperature at the force f, and let $t' = 60°$. Then, as previously shewn, $\frac{459 + t}{459 + t'}$ = the bulk at the temperature t, supposing the bulk at 60° to be one cubic foot. Now, the densities being inversely as the spaces which the vapour occupies, we have $\frac{459 + t}{459 + t'} : 1 :: 10{\cdot}98\,f : \frac{5698{\cdot}6\,f}{459 + t}$ = the weight of a cubic foot of vapour in grains, at the temperature t, and force f.

It has been ascertained that gaseous fluids, which do not chemically combine, mix together without condensation, when the pressure is unaltered; and that, when they are saturated, a cubic foot of air absorbs exactly a cubic foot of steam, as it would exist in a vacuum at the same temperature. (See Gen. Roy's Experiments, Quarterly Journal of Science, Vol. XIII., p. 82, or Daniell's Meteorological Essays, p. 174.

If the bulk of air be a, at the temperature t, and f the force of the vapour at the same temperature, and p the pressure of the atmosphere. Then, since the bulk a of the air mixes with an equal bulk a of the steam at the pressure f; the bulk of the steam at the pressure p will be—as $p : f :: a : \frac{f\,a}{p}$. And the bulk of the whole, after mixture, will be—

$$a + \frac{f\,a}{p} = \frac{a\,(h + f)}{p}$$

(See Tredgold on Warming and Ventilating Buildings, p. 291).

These will be useful when we shall have to estimate what practical results can be obtained in other cases, from the data resulting from the present experiments.

The next consideration is the mechanical effect of the Jet of Steam as a propulsive force. I have already noticed the mode in which Mr. Gurney proposed to apply the Jet, either at the bottom or the top of the upcast shaft. The steam from a boiler, or more than one boiler, being made to pass through small apertures, and so produce a Jet of Steam issuing out of each of such apertures at a very rapid velocity, and acting on the air "by impulse, or *vis a tergo*," as Mr. Gurney expresses it, "driving the whole column of air up the shaft before it.

Mr. Longridge, in a paper read before the Institute of Mining Engineers, explains the action of the Jet as "that of the friction of the steam rushing through the air with great velocity, and carrying it along with it." Whether it be the one or the other, or a combination of both, or a partial vacuum, created by the rapid expansion of the steam, into which the air rushes, and in which manner it is carried along with it, and also, probably, that property of steam to mix with the air; I shall not here, or at this time, enter further upon, but shall proceed to the investigation of the mechanical power given out, or produced by such Jets.

It will be necessary, as in the case of the Furnace, to ascertain the amount of mechanical force exerted by Jets of Steam of given dimensions, and number, in lbs. pressure, per square foot of area of shaft, or horses' power; which we shall first of all do, by ascertaining the evaporating power of a boiler, or a certain number of boilers, such as are used in the collieries where the Steam Jet has been applied.

The form of boiler ordinarily employed is cylindrical, with hemispherical ends, generally 30 feet long, by 5 feet, to 5 feet 6 inches diameter; high pressure, of course. The evaporating power of such a boiler we may take at about 50 cubic feet of water per hour; and as the evaporation of one cubic foot of water per hour is generally taken to represent a horse's power, or 33,000lbs. lifted one foot in height in a minute, we may take one of such boilers, used as a mechanical force, or as made to act as a Jet of steam, as representing 50 horses' power, and so on for any greater number.

We shall now enquire what number of Jets such a boiler will supply with steam,—say, at 40lbs. per square inch.

Mr. Vivian quotes, in his evidence in 1849, "a Cornish boiler, 30½ feet long, 6 feet 2 inches diameter, as supplying a Steam Jet with an opening of ¾ inches square, the safety valve lifting at 50lbs. per square inch;" thus making one Jet, of an area of ·5625 square inches, pass all the steam of such a boiler, at 50lbs. per square inch.

In an experiment which I made at Hetton colliery, with two boilers, each 26 feet long, and 5 feet 4 inches diameter, the evaporation was 93 cubic feet of water per hour, into steam at 40lbs. per square inch; and this quantity of steam was barely sufficient for the supply of 37 Jets ¼-inch diameter,

or 1·8133 inches area. But this evaporation was more than would supply the same number of Jets 3-16ths inch diameter, or 1·0216 inch area.

At Killingworth, I found the evaporation of three boilers, each 34 feet long and 5 feet 1 inch diameter, equal to 170 cubic feet of water into steam at 40lbs. per square inch per hour; and this quantity of steam was also barely sufficient to fully keep up 29 Jets 3-8ths of an inch diameter each, or 3·203 inches area; the boilers being, in this case, very vigorously fired.

At Tyne Main colliery two experiments were made, the Jets being placed at the top of the pit, a short distance from the boilers, and, consequently, little or no condensation. In one experiment there were 33 Jets 3-16ths inch diameter each, and 28 Jets $\frac{3}{8}$ths inch diameter each, the total area being 4·0003 inches. There were two boilers, each 30 feet long, and and 6 feet diameter, with hemispherical ends; the evaporation was 115 cubic feet of water per hour, and the pressure of steam 22·5 per square inch. The boilers were very hard fired, and the steam kept up with great difficulty. The other experiment was with the same boilers, steam at 40lbs. per square inch; 61 Jets 3-16ths inch diameter each,—area of Jets, 1·684 inches; and the evaporation was 109 cubic feet of water per hour, but the steam was blowing off strong all the time, the evaporation being more than the Jets could pass.

The velocity with which elastic fluids rush into a vacuum, is that which a heavy body will acquire by falling through a homogeneous column, equal to the height due to the pressure or elasticity of the fluid; and the velocity with which a fluid of one degree of elasticity will rush into an atmosphere of a different degree of elasticity, is that which a heavy body will acquire by falling through a homogeneous column equal to the height due to the pressure, or difference of degrees of elasticities, of the two fluids.

If we have, therefore, the degree of elasticity or density of steam, we shall know at what velocity such steam will rush into the atmosphere, through a Jet or aperture, out of a pipe containing a continuous supply of steam at such a density. This theorem is well known and is—

$$v = 8\sqrt{86{\cdot}5\ (459 + t'}$$

t' being the temperature of the steam above the pressure of the atmosphere. (See Tredgold on the Steam Engine, p. 89).

This expression of velocity is, however, correct, only when the motion is free from friction, or unretarded. Mr. Tredgold states, "that the velocity through a tube, from two to three diameters in length, should be 6·5 instead of 8."

In the case of the Steam Jet, however, the Jets are necessarily at some distance from the boilers, and the steam will be conveyed from thence by steam pipes of different diameters, and, consequently, we may assume that the velocity will be further diminished. The velocity of steam at 40lbs. pressure per square inch, or 288·4° temperature, will be—

$v = 6{\cdot}5\sqrt{86{\cdot}5\ (459 + 288{\cdot}4)} = 1652{\cdot}7$ feet per second, the velocity with which the steam would issue from the Jets.

The quantity of water evaporated at Hetton, was 93 cubic feet per hour, we then have,

$$\frac{93 \times 506 \times 144}{3600 \times 1{\cdot}8133} = 1038 \text{ feet per second,}$$

the velocity with which 93 cubic feet of water converted into steam of 40lbs. pressure, per square inch, 506 bulk per minute, would pass through an aperture of 1·8133 inches in area. And at Killingworth $\frac{170 \times 506 \times 144}{3600 \times 3{\cdot}203} =$ 1074 feet. And at Tyne Main, No. 1 experiment, $\frac{115 \times 959 \times 144}{3600 \times 4{\cdot}003} = 1102$ feet; and No. 2 experiment, $\frac{109 \times 504 \times 144}{3600 \times 1{\cdot}634} = 1311$ feet per second, the velocity of the steam out of the Jets. The theoretical expression of these experiments being about 4·25 on the average, (the last experiment not passing all the steam,) instead of 6·5 as given by Tredgold; which is probably the more correct expression, as Tredgold gives 5· as the expression, when the steam issues through a thin plate, and 5·45 through a tube of two or three diameters in length, projecting inwards.

Assuming 4·25 as the expression, we would have the velocity with steam at 40lbs. = 1080·6 feet per second; and at 50lbs. = 1088·4 feet per second.

Having, thus, the number of boilers, or area of surface of evaporation; and reckoning in round numbers, 3 square feet of surface of evaporation for each cubic foot of water evaporated. We shall know the mechanical power employed in any Steam Jet apparatus,—and resolving the quantity of water into steam of the elasticity intended to be used, and and adopting the theorem

$$v = 4{\cdot}25\sqrt{86{\cdot}5\ (459 + t'}$$

t' being the temperature of the steam equivalent to the elasticity intended to be used, we can also determine the number of Jets to be used.

And if we wish to know the number of horses' power of the steam employed in the Jets, or the pressure per square foot of area of shaft, we can also determine these.

Thus, suppose the pressure of steam employed in the Jets to be 40lbs. per square inch = 288°4 Fah. Then $4{\cdot}25\sqrt{86{\cdot}5\ (459 + 288{\cdot}4)} = 1080$ feet per second the velocity with which the steam will issue from the Jets.

Take the case of Tyne Main. 61 Jets 3-16ths of an inch in diameter each = 1·6843 inch area: we have, as above, 1·6843 inches of steam, at 40lbs. pressure, with a velocity of 1080·6 feet per second. Then $\frac{1080{\cdot}6 \times 1{\cdot}6343 \times 60}{144}$ = 758·37 cubic feet of steam per minute, and as the bulk of steam as compared with water is as 506 : 1 ; we have $\frac{758{\cdot}37}{506} = 1{\cdot}5$ cubic feet of water per minute, or 90 cubic feet per hour required to be evaporated to supply Jets of the area of 1·6843 inches, with steam at 40lbs. pressure per square inch.

And if we require to know the pressure per square foot of area of shaft, in the same terms as Table III. of Furnace Ventilation, we have 758·37 cubic feet of steam, to act upon an area through the cylinders, of 40·25 feet, with steam at 40lbs. per square inch pressure, now $\frac{758{\cdot}37}{40{\cdot}25} = 18{\cdot}84$ feet per minute, the quantity of steam supplied at 40lbs. But the velocity of the air is 1231·6 feet per minute, (viz., 49·574 cubic feet of air per minute passing up the shaft, the area of which is 40·25 feet,) therefore, as 18·84 feet : 1231·6 feet :: 40lbs. : ·6118lbs. pressure per square inch, or ·6118 × 144 = 88·10lbs. per square foot of area of shaft.

And $\frac{88{\cdot}11 \times 40{\cdot}25 \times 1231{\cdot}6}{33{\cdot}00}$ = 132 horses' power.

RESISTANCE OF THE AIR IN MINES.

I shall now proceed to the consideration of the resistance of the air in mines, or to *C*, and, as previously noticed, this is a most important and a most difficult undertaking; requiring a much more elaborate and extensive investigation than I can pretend to bestow upon it, on such an

occasion as the present. I have found it necessary to enter upon it on a somewhat extensive scale, however, in order to obtain data whereby to compare the effective performances of the different systems of ventilating power; and I trust such researches, and the data which I have obtained from the experiments I have found it necessary to make in illustration thereof, will not be without their value, in the consideration of the Ventilation of Mines generally.

The mode by which mines are ventilated, is by conveying the atmospheric air through all the passages, drifts, and openings, which have been made in the excavation of the coal, so far as it as practicable to do so. In what is called the goaf, or goaves, viz., large spaces where the coal has been entirely taken away, or excavated, and where the roof has been allowed to fall, or where the upheaving of the bottom of the mine has closed, entirely or partially, the space out of which the coal has been excavated, the atmospheric air cannot be made to traverse; and in those cases it is carried along the edges of those spaces, or along the edges of the goaves. But in all other parts of the mine the atmospheric air is made to traverse, to sweep away, mix with, or dilute the noxious gases which are evolved, either in the operation of working the coal, or in the old workings of the colliery, and so convey them to the surface harmlessly.

In colleries which have been a long period in working, and in some of the deep mines, where the expense of sinking is very great, the extent of the workings, and of the air passages, are very extensive, extending to many miles, through which it is necessary that the air should be made to traverse.

It has been generally understood that Mr. Spedding, of Whitehaven, was the first who attempted anything like a system of what is called "coursing the air," or carrying the air through the workings of a colliery, by a system of stoppings, or brick walls, closing up some of the passages, and forcing the air along others, and so causing it circulate through all the old or left-off workings. Previously to this being done, it would appear that the air was only made to circulate around those parts of the mine where the men were at work.

According to Mr. Spedding's System, the air was taken from the downcast shaft, and circulated in one unbroken current through the whole of the workings and waste. Mr. Buddle, finding this difficult to do, in

the extensive collieries of Northumberland and Durham, adopted the system of what is called "splitting the air," or,—instead of carrying the air in one unbroken current from the downcast, around all the workings, to the upcast shaft, to split such current into sub-divisions, and which also shortened the length which each current had to traverse.

The advantage of this is very obvious, the resistance of a current of air being directly as the length of the current, and the square of the velocity of the air; the current being shortened, the resistance in that respect is diminished, in the ratio of the diminution of the length of run; and the current being divided, the initial velocity is also reduced, and this diminishes the resistance in the ratio of the square of the velocity of the current, before and after being split. This has been carried to a great extent in some of the extensive collieries, even as many as 20 to 30 splits, or separate currents existing in some of the mines.

It would have been extremely useful if, in an enquiry of this kind, we could have ascertained and laid down some practical rules by which the resistances of the air in one colliery could be correctly compared with that of another; we should then have been able, by comparing the practical effect of the Jets in one colliery with the Furnace in another, to have more readily determined their relative merits.

In the present state of our information this, however, cannot be done with any degree of accuracy. I have obtained the length of the air courses of several collieries, their area, the quantity of air traversing each split, and as much information as I could obtain; but the results are not such as I can present with confidence. There are so many elements requisite to determine with sufficient accuracy, in a practical point of view, the power required to produce a given velocity of current, or a determined amount of Ventilation; that I find it would take more time than has been allowed me, to make the requisite experiments and investigations to determine this most important question.

In comparing two collieries, one with Furnace, and the other with Steam Jet Ventilation, we should have to take into consideration, in a conclusively practical manner, all the comparative effects as regards the length of the air courses,—their area, and the superficies of the drifts, the velocity with which the air in each of these splits travel. We should also have to take into account the manner in which the splits are taken off

from the main currents. Whether they are independent splits passing from one shaft to the other, without interference with any other current, or whether they are currents detached from the main current, made to travel certain workings, and again join the main current,—and probably even some of those splits or detached currents are again subdivided, and either made to join the original main current, the detached current, or probably some other current.

I would simply direct the attention of the enquirer to the system of the Hetton Colliery Ventilation, Appendix No. I. There are, in that colliery, 5 main currents of air,—these are subdivided into 35 splits, and, as will be seen by the statement, some of these splits proceed for a certain distance united, are then subdivided, and in some cases, are mixed with other splits,—and in all these peregrinations, the area of the air courses vary every yard ; and consequently the velocity of the current, which form so important an element in the resistance, varies likewise. After great labour and consideration, I have despaired in deducing, even from a variety of cases, any thing like correct data, whereby to compare dissimilar cases with each other. The conclusion I have therefore come to is, that the only correct mode of comparing the two systems of Ventilation, is to ascertain their comparative powers at the same colliery, and under as precisely the same circumstances as possible.

In the investigation, however, of this subject, it will be necessary to determine the predominant principles which govern the passage of the currents of air through coal mines, without which we cannot correctly ascertain the comparative merits even at the same colliery.

In the investigation of the resistance of the currents of air in a mine, we must take it into consideration the lengths of the different currents,—there will be in every mine what may be termed the main or ruling current, similar to what is termed the ruling gradient of a Railway, viz. :—the current or currents which are the longest, and which present the greatest resistance, and by which the several minor currents are ruled or regulated.

In determining the resistance of the currents of a mine, it is not enough that we should take the number of splits,—their respective lengths,—their areas, and either obtain an aggregate length, and mean area,—or yet an average length, and a mean area. These would not give

accurate representations of the aggregate resistances. And as in the course of this investigation we shall have to advert to this, and to compare the amount of the resistance of the Ventilation of one colliery with another; it is necessary that this should be thoroughly understood, though it may appear tedious and prolix.

I shall take a case which may be tabulated as follows, and which is shewn on sketch in Fig. 12, Plate II., where *A* represents the downcast, *B* the upcast shaft, and Nos. 1, 2, 3, 4, and 5, the different currents of air.

Table shewing the Ventilation of a Colliery.

No. of Currents.	Quantity of Air, in cub. ft. ℘ min.	Distance in feet each Current of Air travels.
		feet.
No. I.	38,000	 19,470
II.	4,400	 6,400
III.	13,020	1518+1650+7768 =10,836
IV.	5,400	1518+1650+4470 = 7,638
V.	7,500	.....1518+3300 = 4,818
VI.	14,000	 210
TOTAL...	82,320	Average distance..... 8,229

The ruling current here is No. 1, that of 38,000 cubic feet per minute, traversing a distance of 19,470 feet. Supposing the velocity of the air to be the same in all the currents, then, the resistance being as the length of the current, the natural tendency of the air would be to take the nearest route to the upcast, and so abstract a quantity of air from the longest route, or from No. 1; a regulator is, therefore, put into the air course, No. 2 at *A*, another into No. 3 at *B*, into No. 4 at *C*, and into No. 5 at *D*.

All those regulators contract the area of the passages, produce a corresponding increase of velocity in the current; and as the resistance is as the square of the velocity of the current, the area is so contracted until the resistance of the air through the regulator of the minor currents is equal to that of the long current, and then there is an uniform resistance produced, and each current then retains the quantity of air allotted to it.

It will be seen, however, that each minor current of air, though the distance it travels is much less than that of the longest current, is made to have the same resistance; and that, therefore, the aggregate resistance will be represented by the total quantity of air multiplied into the length of run of the longest current, or by 83,000 × 19,470. This has an important bearing upon the ventilation of extensive coal mines, and on the subject under consideration.

Assuming this to be the correct view of the case, then the difficulty is considerably diminished in estimating the amount of resistance, or drag of the air in any coal mine; as, having once obtained the amount of resistance by experiment or otherwise, of any defined length of current, and area of air passage, we have only to take the length of the longest current, its area, and superficies, by which to ascertain the resistance of all the other currents, and so obtain the aggregate resistance, or *C*.

To determine the value of *C*, even with this limitation, is, however, attended with considerable difficulty: the variation in the dimensions of the air courses, passages, goaves, and route which the one main current has to take, is so great, that it can only be determined by experiment—and when determined in one case, it is no rule for another, the main current of one pit differing in all these circumstances very much from another.

Mr. Hawksley, of Liverpool, has given a theorem, which is the result of a great many experiments on gas conveyed in pipes of many miles in extent, which is generally considered to be the most accurate that has been put forth, and which having been deduced from pipes of a uniform area, is likely to be much more accurate than any theorem deduced from the variable area, and superficies of a current of air in a coal mine.

Let v = Velocity of air in feet per second.
T = Temperature of the upcast shaft.
D = Depth of shaft in feet.
t = Temperature of the downcast shaft.
s = Sectional area of the air courses in feet.
m = Corresponding margin, or superficial area of dimensions of air courses in feet.
l = Length traversed by air in feet.

$$v = 96 \sqrt{\frac{\left(\frac{T - t}{T + 448}\right) D\ s}{l\ m + 360\ s}}$$

I give this theorem, as I believe it has not hitherto been published, and because it has been found to be extremely correct in passages, or through pipes with smooth superficies; the co-efficient will require to be altered in its application to coal mines, but it may probably be of utility in the further elucidation of the subject, when a general co-efficient deduced from numerous experiments has been obtained.

An attentive consideration of this part of the subject, shews of what importance it is to attend to the most judicious and proper distribution of the air in a Coal Mine of even moderate extent. It is in vain to indulge in improved systems, or applications of powerful Ventilating Powers, if a proper distribution of the air is not carried out in the mine when it is obtained. It may be all thrown away by increased resistances arising from an improper system, or distribution of the air through the passages of the mine, and we shall see afterwards that the same Ventilating Power in different cases produces very different results.

This is obvious when we keep before us, that the resistance of the air through a mine is directly as the length of the main, or ruling current, and as the square of the velocity with which the air is made to travel—not through all the length of the air passages, but through even an inconsiderable distance. Mr. Gurney speaks of the "Vena Contracta" as a powerful obstacle in the Ventilation of Coal Mines. Every regulator is a Vena Contracta,—every obstruction, or diminution in the area of the air passages below the proper dimensions, is a Vena Contracta; all operating in a geometrical ratio to obstruct and diminish the quantity of air, and to increase the resistance to the ventilating power.

Let L = the length of the air courses, A = the area representing the velocity of the air, and P = the Ventilating power, then $P = L \times A^2$. Thus, taking the case before us, the average length of the six currents is 8229 feet, the entire length is 49·372 feet, L in the one case being 1, and in the other 6. Supposing the air is equally divided amongst six drifts in the one case, and a single continuous current in the other, the difference of Ventilating power required will be $6 \times 1^2 = 6$; and $6 \times 6^2 = 216$, or 36 times the power in the one case as in the other; and taking the No. I. current as the ruling one, and supposing the other minor currents to be obstructed by regulators, or area of drifts, so as to equalize the resistance, the difference will be as $36 : \left(6 \times \frac{19470}{8229} \times \frac{82{\cdot}320}{38{\cdot}000} = \right) 66{\cdot}62$, or nearly

double the power. Too much attention cannot, therefore, be paid to the proper distribution of the air, so as to have the shortest possible air currents, and the largest area of air courses, consistently with having the requisite quantity of air in each current, and with economy and the practicability of obtaining spacious air courses.

WATER GAUGE.

We have now practically to ascertain the value of *C*, and for this purpose I have made use of the Water Gauge. This is a very simple, but very effective instrument. It is in the form of a bent glass tube open at both ends, shewn in Fig. 1, Plate II, and the mode of application is thus.

A, has been made to represent the pressure or weight of column of the air in the downcast shaft of a mine, *B*, the weight of the column of air in the upcast shaft; and we have seen, or it is indeed, apparent, that if there was a free communication between them along the drift or passage *C*, Fig. 1, Plate I, a current of air would in Furnace Ventilation be produced continuously, so long as the temperature of the column *B*, was greater than that of *A* : and if any other system of ventilation is adopted either to force the air down the shaft *A*, or to pump or force the air up the shaft *B* ; or if a compound system is adopted, to force the air down the shaft *A*, and at the same time pump or force air up the shaft *B* ; so long as these mechanical forces act, so long will a current of air be produced down the shaft *A*, along the passage *C*, and up the shaft *B*.

When we employ all or any of the mechanical powers to ventilate a Coal Mine, we close the passage *C*, and so cause the air to pass around the workings, as explained in Fig. IV., and which is generally done by placing a door at *A*, in the passage *C*. It is now quite clear that the difference of pressure between one side of this door, and the other, is a correct measure of the force or power required to propel the current of air around the workings of the mine ; and a Water Gauge placed in this door, one end being open to the upcast, and the other end open to the downcast, the difference of height of water in the two columns will exhibit a correct admeasurement of the pressure or force required to produce the different currents of air. It has been in this manner that the force, or the resistance of air at the different velocities, in these experiments, was ob-

tained. This will be more clearly shewn by a reference to the diagram, Fig. 12, Plate II., where *a* represents the door (one being opened) on which the Water Gauge was applied.

The "Water Gauge," therefore, placed in these doors indicates the force or pressure which is required to compel the air to traverse the workings, or, in other words, indicates the measure of force required to overcome the drag of the air around these workings or around the mine ; and being a correct indicator of the power or force required to cause the current to traverse the workings of a coal mine, (such as represented in the diagram,) is the best instrument to measure, not only the actual amount of such force, but also the power required to produce currents of different velocities, and can also be made use of, to ascertain the relative power of different ventilating forces.

The Water Gauge, however, it is necessary to remark, does not represent the entire amount of the ventilating power. It is an indication of the difference of pressure between one side of the door and the other, and indicates correctly the resistance and power required to keep in motion the different currents of air traversing the mine after passing one side of the doors until they return to the other, but it does not indicate, or measure the force required to propel the air over the Furnace, and up the shaft.

In estimating, therefore, the relative amount of power employed in the different systems of Ventilation we must take these into consideration, and we shall see hereafter that this is important. In our investigations we shall, therefore, endeavour to ascertain, the power required to propel the air around the workings ; and also, that which is required to propel it up the shaft ; or, the resistance opposed to the ventilating power, in propeling the air around the workings, and the resistance opposed by the Furnace and column of heated air in the shaft in Furnace Ventilation, in the one case ; and by the column of heated air and steam in the shaft, in the case of Steam Jet Ventilation, in the other.

The Water Gauge placed at the doors *a* in the passage shewn in the diagram, will not, as before stated, indicate the resistance in the upcast shaft, or the power required to force the air over the Furnace, or through the Jet apparatus ; but, if we know the total amount of ventilating power employed, (whatever that power may be) and if we can with the

Water Gauge measure the amount of power required to force the air around the workings of the mine, or what may be called the effective ventilating power, we can then obtain the remaining resistance or loss of power by the different modes of ventilation, from whatever cause such loss may arise. The Water Gauge, therefore, we shall find to be a most useful instrument in ascertaining the practical, or effective amount of ventilating power, or of the resistance to Ventilation, and consequently of the value of *C*.

EXPERIMENTS MADE TO DETERMINE THE ACTUAL, AS WELL AS THE RELATIVE POWERS OF THE FURNACE AND STEAM JETS, AS VENTILATING POWERS.

The Collieries at which these experiments were made, were the Hetton, Killingworth, and Tyne Main Collieries. They are what may be called deep collieries being respectively 900, 690, and 672 feet in depth, and an experiment at the Norwood Colliery, 252 feet in depth.

At Hetton Colliery the Jets were placed at the bottom of the pit, the boilers, and consequently the fires, being also at the bottom of the pit; consequently the experiments at the Hetton Colliery embrace the ventilating power by—

1—Natural Ventilation.	
2—Engine Fires alone	At the bottom of the pit.
3—Engine Fires and Steam	
4—Engine Fires, Steam, and Jets	
5—Furnace	
6—Furnace, Engine Fires, and Steam	
7—Furnace, Engine Fires, Steam, and Jets...	

At Killingworth the Jets were placed at the bottom, and likewise at the top of the pit, but the boilers being placed on the surface, the steam was taken down the shaft in pipes; and, therefore, an opportunity presented itself of ascertaining by experiment—

Natural Ventilation.	
Steam	At the bottom of the pit.
Steam and Jets	
Furnace.....	
Furnace and Jets	
Jets	At the top of the pit.
Furnace at bottom, and Jets ...	ditto.

These experiments would have been sufficient to test the comparative powers of Furnace and Steam Jet Ventilation, in almost all the varieties in which they can be applied, and likewise the actual amount of their ventilating powers in the several modes of application; but in the experiments on the power of the Jets, as a propulsive force alone, unaided by the rarefaction of the air in the shaft, I did not consider the experiments at Killingworth quite conclusive. It is only by placing the Jets at the top of the pit that the propulsive force can correctly be ascertained. The Killingworth shaft is of an uniform area, and only 30·08 square feet. When the Jets and cylinders were placed in the shaft, and all the openings, except through the cylinders, closed up; the area was reduced to 19·14 square feet, which I considered too small an area to test the actual powers, though the experiment was good comparatively, the obstruction applying equally to the Jet and the Furnace, as the air from both passed through the cylinders.

The Tyne Main Pit is 8 feet diameter, or 50·265 feet area, except about 34 yards, commencing 84 yards from the surface, where the tubbing is lined with fire-brick, and where the diameter is only $7\frac{1}{2}$ feet, or 44·178 feet area. For about 70 feet at the top of the pit the diameter is, however, 9 feet, and this presented an opportunity of placing within this increased area a larger number of Jets, and also to obtain a larger area for the air to pass through the cylinders, viz., 40·257 square feet, which may be considered a sufficient area, to test the impulsive force of the Jets placed at the top of the pits.

The experiment at Norwood Colliery was made to test the comparative merits of Furnace and Jet Ventilation, in pits of small depths; the Jets being placed 180 feet from the surface, and the Furnace 252 feet from the surface.

I shall now describe the mode in which the experiments were conducted.

Hetton Colliery Experiments.

The Hetton Colliery, or that part of it at which the experiments were made, comprises one upcast shaft, called the Blossom Pit, and two downcast shafts—the Minor, and Eppleton Shafts. The two former shafts are 900 feet in depth, and the latter 1,080 feet. A small portion of air passing up the upcast shaft proceeds from another downcast shaft, called the

Elemore, but the great bulk of the air of that shaft passes up a separate upcast, which was not made the subject of experiment. The upcast, or Blossom Shaft, is 153 feet in area, and the two downcasts are respectively 98 and 58 feet area = 156 feet.

The ventilating power of the Hetton Colliery is obtained from three Furnaces, one 9 feet in width, and the other two, 8 feet each.

Fig. 3, Plate I., is a section of the Hetton Shaft, near the bottom of the pit, shewing the furnaces. *A* being the shaft or pit, *B B* the two Furnaces, over which the air from the Minor Pit and Elemore passes, and *C* the Furnace over which the air from the Eppleton Pit passes,—*D D* being the two sloping drifts up which the heated air from the furnaces pass into the shaft. *B B*, Fig. 6, is an elevation of the two Minor Pit Furnaces, and *C*, Fig. 7, that of the Eppleton Pit Furnace.

E, Fig. 3, shews the two boilers, *a a*, placed at the bottom of the pit for working two underground engines, and which were used in supplying Steam for the Jets—the heated air and steam from the boilers passing up a staple *F* into the sloping drift *D*, and so into the shaft *A*. *G* shewing the position in which the Jets were placed in the shaft, the steam being conveyed along the pipes *e e*. The diameter of the steam pipes were 6 inches. Fig. 8 is a plan shewing the distribution of the Jets in the shaft at *G*. Three sets of Jets were used, viz., $\frac{3}{16}$, $\frac{2}{8}$, and $\frac{3}{8}$th of an inch diameter each respectively, 37 Jets being the number in each case.

The workings of the Hetton Colliery, ventilated by the aforesaid shafts, are very extensive, spreading over an extent, in the Hutton seam of upwards of 2000 acres; comprising, coal partially worked, or standing in pillars, and coal entirely worked away or goaf. Table I., Appendix, is a Synopsis of the Ventilation—shewing the distances which the different currents of air traverse; either together or separate, and which also shews the extent of the Ventilation, and the manner in which the air is split, and distributed throughout the workings.

It must be observed that there are three seams or beds of coal in working at Hetton Colliery—the Hutton Seam 900 feet; the Low Main coal 780 feet; and the Main coal 660 feet from the surface. The Furnaces are 900 feet from the surface, and in the Hutton seam, and though these Furnaces embrace the Ventilation of the entire workings in all the seams, the air from the Low main, and Main coal seam do not pass over them,

but pass into the upcast shaft at their respective depths from the surface ; and, as will be seen by the Synopsis of the Ventilation, the quantity of air passing around the workings of the Low main coal seam is 29·200 cubic feet per minute, and in the Main coal 29·950 cubic feet per minute.

Tables I., II., III., and IV., are the experiments made to ascertain the actual, as well as the comparative performances of the Furnace and Steam Jet, in producing Ventilation. Tables V., VI., and VII., are those made to ascertain the consumption of coal, and power expended in the two systems, and to ensure accuracy, were carried on for a period of 12 and 24 hours respectively. Table VIII. being a summary, or general result of the three latter experiments.

In the prosecution of these experiments, every care was taken to ensure accuracy. The temperatures in the upcast shaft were generally taken by two Thermometers, suspended in the shaft at the different depths at the same time,—self-registering were used at first, but after having had several broken, I was obliged to abandon the use of them, and to use common Thermometers with the bulbs wrapped with cotton, to prevent them cooling down in taking them out of the shaft, but keeping them a sufficient time in the shaft to register the temperature. The dampness of the shaft, and the unavoidable variation in the temperature, as the Furnaces or engine fires were more or less urged, produced some discrepancies in this result ; which, however, though it would have been more satisfactory in a scientific point of view, if a strictly accurate result could have been obtained, will be found not to have effected the general result, and were as accurate, as I believe they could be, under the circumstances, obtained. The quantity of air was measured with gunpowder, within the downcast shaft ; the difference of specific gravity between the gunpowder smoke, and the air passing down the shaft, will slightly effect the actual quantity, making the recorded quantities rather less than the actual ; but the comparative result will not be effected thereby, in any appreciable degree. However, it may be made the subject of calculation if requsite. Every care was taken to ascertain the amount of water gauge, and the quantity of coal consumed, and also the quantity of water evaporated, and the elasticity of the steam employed in the Steam Jet experiments. The boilers have, which is called "flash" flues, and, consequently the great quantity of coals used in the evaporation of a cubic foot of water is rather high ; this can, however, also be made the subject of calculation if required.

TABLE I.

Synopsis of Experiments on Furnace and Steam Jet Ventilation at Hetton Colliery, October 12th, and November 3rd, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Surface.	Bottom of Downcast.	Bottom of Upcast.	Surface.	Bottom of Downcast.	In Return Air.	Upcast at 10 fathoms.	Upcast at 55 fathoms.		
October 12th. 7·0 P.M.	Three Furnaces and Engine Fires on, the Steam blowing into Upcast at 45lbs.; Pit just done working	30·091	31·051	30·076	48°	50°	66° 75	120°·2	148°·7	1·4	198,261
9·0 ,,	Three Furnaces only; Engine Fires damped	30·101	...	...	46	48	67	104·3	126·6	1·3	187,580
Nov. 3rd. 7·15 P.M.	Three Furnaces and Engine Fires, the Furnaces rather low	29·252	...	...	47	49	66·5	...	...	1·1	
7·30 ,,	Three Furnaces in good order	...	...	...	...	...	...	155	150	1·4	208,443
	31 Jets, ¼-inch diameter, set on at 7·52 P.M.; Steam 35lbs. per square inch	...	...	...	...	...	...	153	168		
	Jets taken off at 8·19 P.M., and set on again at 8·43 P.M.										
9·0 ,,	Jets and three Furnaces	29·271	...	...	...	...	...	169	180	1·5	212,907

TABLE II.

Synopsis of Experiments upon Steam Jet and Furnace Ventilation at Hetton Colliery, October 29th, 30th, and 31st, 1852.

Time.	Description of Experiment.	Barometer.			Temperatures.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Bank.	Bottom of Downcast.	Bottom of Upcast.	Bank.	Bottom of Upcast.	In Return Air.	Upcast at 10 fathoms.	Upcast at 55 fathoms.		
October 29th.											
6·0 P.M.	Three Furnaces and Engine Fires	29·120	..	..	51°·5	..	..	170°	..	..	
6·30 ,,	Ditto and Steam just blowing off into Shaft; Pit just done working	..	..	..	..	..	..	..	180°	..	205,615
7·30 ,,	Ditto	29·1	..	..	48·5	..	..	173	180	1·5	201,274
9·00 ,,	Three Furnaces, Engine Fires, and 37 Steam Jets $\frac{3}{16}$ths. diameter.—Steam 40 lbs. per square inch	..	..	29·93	..	50°·5	64°·5	171	180	1·55	205,636
October 30th.	Furnaces put out and Engine Fires damped at 10·40 P.M. on October 29th, and remained out until 6·30 A.M. on October the 30th.										
6·30 A.M.	Natural Temperature	..	..	..	..	..	..	83	85	.4	130,890
	At 6·30, Engine Fires lighted.										
9·30 ,,	Steam blowing off into Shaft	29·03	..	30 06	45	..	64	92	98	·6	139,176
	At 10·30, 37 Jets $\frac{3}{16}$ths diameter: put on Steam at 50lbs. per square inch.										
12·30 ,,	Engine Fires and Jets	..	..	30·06	..	47°	64	99	105	..	149,284
2·30 P.M.	Ditto	..	..	..	..	..	..	98	..	..	150,873
	At 2·50, Furnaces lighted, Jets on as well as Furnaces.										
6·0 ,,	Ditto	..	..	..	..	..	..	155	164	1·5	207,093
	At 7 o'clock P.M., Furnaces put out and Engine Fires damped, and remained so until 6 o'clock A.M., 31st October.										
October 31st.											
6·30 P.M.	Natural Temperature	28 9	..	..	52	..	..	79	85	·35	104,414
	Furnaces lighted at 6·40 A.M.										
9·0 ,,	Furnaces alone on	..	..	29·75	..	..	69	150	172	1·35	201,960

TABLE III.

Synopsis of Experiments upon Steam Jet and Furnace Ventilation at Hetton Colliery, November 13th, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.					Water Gauge in inches.	Quantity of air in cubic feet per minute.
		Bank.	Bottom of Downcast.	Bottom of Upcast.	Bank.	Bottom of Downcast	In Return Air.	Upcast 10 fathoms.	Upcast 65 fathoms.		
Nov. 12th.											
6·0 P.M.	The Furnaces put out, and Engine Fires damped, and remained so until 8·39 A.M., November 13th	29·527									
Nov. 13th.											
8·30 A.M.	Natural Temperature	29·395	...	...	39°	...	...	...	80°	0·50	123,463
10·30 ,,	Engine Fires only, Steam just blowing off; at 10·40 Engine Fires set away	...	30·25	...	...	47°	...	...	89	0·60	132,053
11·30 ,,	Engine Fires, and Steam blowing into shaft	...	...	29,325	...	...	67° 30	87°	81	0·60	139,847
	37 Jets, ¼-inch diameter, set on at 11·56; Steam 40lbs. per square inch; Evaporation of Water, 1·55 cubic feet per minute.										
12·30 P.M.	Engine Fires and Jets	29·30	...	...	41·25	...	...	88	94	0·8625	164,376
1·30 ,,	Ditto	...	...	...	...	...	68·5	97	97	0·855	163,614
	At 1·39 Jets taken off.										
3·48 ,,	Jets still off and Engine Fires damped	29·293									
	Natural Ventilation	...	...	...	...	47	...	...	75	0·55	127,145
	At 4·3 lighted the three Furnaces.										
4·30 ,,	Three Furnaces alone	...	...	...	...	...	...	163	178	1·75	211,193
5·30 ,,	Ditto	...	...	...	...	...	68	179	211	1·95	225,176
	At 5·40 Boiler Fires put away, Furnaces on also.										
6·6 ,,	Three Furnaces and Engine Fires	...	...	...	...	...	...	194	226	2·00	229,918
	At 6·10 the Jets set on; Evaporation 1·55 cubic feet per minute of water.										
6·26 ,,	Three Furnaces, Engine Fires, and Jets	29·287	...	...	...	...	...	200	...	2·05	234,118

TABLE IV.

Synopsis of the Experiments on Furnace and Steam Jets at Hetton Colliery, December **11*th*,** 1852.

Time.	Description of Experiment.	Barometer.			Temperatures.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Bank.	Bottom of Downcast.	Bottom or Upcast.	Bank.	Bottom of Downcast.	In Return. Air.	Upcast at 55 fathoms.	Upcast at 65 fathoms.		
Decem. 11th.	Furnaces put out as well as Engine Fires, at 8 P.M., December 10, and remained out until 8 A.M., Dec. 11.										
8·0 A.M.	Natural Ventilation	29·189	...	...	51°	...	...	73°	...	...	117,908
	Engine Fires put away, and Water in Boiler raised to 45 lbs. per square inch, and kept at that pressure.										
11·30 ,,	Steam just blowing off	...	29·85	...	53	...	...	81	...	0·4	121,464
12·30 P.M.	Boiler Fires put away and Steam blowing into Shaft, same as when Jets were on, two Boilers, each 26 feet long, 5 feet 4 inches diameter; circular ends	...	...	29·8	55	...	68°	82	85°	0·55	129,569
	Jets set on at 12·40. 37 Jets $\frac{1}{4}$ inch diameter = in Area 1·8133 inch	...	...	...	55	...	...	89	93	0·67	149,401
1·30 ,,	Steam at 40 lbs. per square inch	...	...	...	...	...	...	87	90	...	140,923
	Cleaning Fires from 1·40 to 3·20.										
3·30 ,,	Jets on; Steam 45lbs.	29·107	...	...	...	...	...	90	94	0·70	147,707
4·16 ,,	One Furnace lighted at 3·40, Eppleton Furnace, only, 9 feet broad and Bars 6 feet, only 4 feet of Fire Grate	...	29·8	...	56	...	...	95	97	0·80	166,826
5·30 ,,	Jets set on in addition to Furnace; Steam at 45lbs.	...	...	...	55	...	...	124	128	1·17	194,075
5·35 ,,	The other two Furnaces lighted; Jets on	29·187	...	...	56	...	...	166	170	1·45	

TABLE V.

Synopsis of Experiments made at Hetton Colliery, with Three Furnaces, during Friday night and Saturday, the 26th and 27th Nov., 1852.

Time.	Temperatures. Bank.	Temperatures. 55 Fathoms.	Minor Pit. Area 98 Feet. Cub. Ft. ℔ min.	Eppleton Jane Pit. Area 58 Feet. Cub. Ft. ℔ min.	From Isabella Pit north way through Lyons waste to Blossom upcast. Cub. Ft. ℔ min.	Total quan. of Air passing down the downcast shafts. Cub. Ft. ℔ min.	Water Gauge in Inches.	Consumption of Coals, &c.
At 8 o'Clock, P.M.	48°	130°	141,120	65,936	8,743	215,799	1·25	In the 24 hours the 2 Furnaces, *B B*, consumed 15,960 lbs. of Coals, and the Furnace, *C*, 11,200 lbs. of Coals; altogether in the 24 hours, 27,160 lbs., which is equal to 18·86 lbs. per Minute, and 11,066 Cubic Feet of Air for each lb. of Coal consumed.
9 ,,	48	140	135,692	67,719	10,200	213,611	1·20	
10 ,,	46	135	135,692	67,719	9,415	212,826	1·20	
11 ,,	48	128	135,692	65,936	8,743	210,371	1·20	
12 ,,	46	130	135,692	65,936	8,743	210,371	1·20	
1 o'Clock, A.M.	45	138	130,666	65,936	9,415	206,017	1·20	
2 ,,	47	144	135,692	65,936	8,743	210,371	1·20	
3 ,,	46	125	135,692	67,719	10,200	213,611	1·20	
4 ,,	44	135	135,692	65,936	10,200	211,828	1·20	
5 ,,	45	135	135,692	65,936	8,743	210,371	1·20	
6 ,,	46	138	130,666	65,936	8,160	204,762	1·10	
7 ,,	42	137	135,692	65,936	9,415	211,043	1·05	
8 ,,	44	138	130,666	65,936	8,743	205,345	1·15	
9 ,,	45	130	133,132	62,640	8,743	204,515	1·20	
10 ,,	47	128	130,666	65,936	8,743	205,345	1·05	
11 ,,	49	129	130,666	64,246	8,743	203,655	1·15	
12 ,,	50	120	130,666	65,936	8,743	205,345	1·10	
1 o'Clock, P.M.	54	128	130,666	65,936	8,743	205,345	1·10	
2 ,,	55	125	130,666	65,936	8,743	205,345	1·10	
3 ,,	55	125	130,666	65,936	9,415	206,017	1·20	
4 ,,	52	120	130,666	65,936	8,160	204,762	1·20	
5 ,,	48	120	135,692	67,719	8,743	212,154	1·15	
6 ,,	48	120	135,692	65,936	8,743	210,371	1·15	
7 ,,	51	124	130,666	65,936	8,743	205,345	1·05	
8 ,,	50	128	130,666	67,719	8,743	207,128	1·10	
Average	44°	130°	133,394	66,094	8,978	208,466	1·20	

TABLE VI.

Synopsis of Experiment made at Hetton Colliery with the Steam Jets, 37 *in number,* $\frac{1}{4}$ *of an inch in diameter.—January* 3, 1853.

Time.	Temperatures. Bank.	Bottom of Downcast.	In return Air.	10 Fath.	65 Fath.	Minor Pits. Area 98 Feet. Cub. Ft. ℔ Min.	Eppleton Lane Pit. Area 58 Feet. Cub. Ft. ℔ Min.	Elemore portion of Air through Lyons Waste. Cub. Ft. ℔ Min.	Total quan. of air passing down the downcast sh. Cub. Ft. ℔ Min.	Water Gauge. In.	Pressure of Steam ℔ ℔ s.in.	Consumption of Coals.
At 6 o'clock,	..	..	..	..	..	..	41,760	6,800				2 boilers, each 26 ft. long, 5 ft. 6 in. diam., with hemispherical ends.
7 [A.M.	..	..	..	75°	85°	88,200	50,112	6,800	145,112	·65		18,200 lb. of coals consumed in 12 hours is 25·28 lbs. ℔ min., and consequently 6,400 cub. feet of air ℔ min. for each lb. of coal consumed. 1498·25 cub. feet of water evaporated in 12 hours is 117·35 cub. feet ℔ hour, or 58·67 cub. feet for each boiler, the evaporating surface being 394 sq. ft.
8 ,,	..	..	..	85	90	98,000	48,185	6,800	152,985	·80	35	
9 ,,	45°	47°	..	85	90	100,800	56,946	7,650	165,396	·80	35	
10 ,,	..	..	..	90	90	99,380	56,946	7,650	163,976	·80	40	
11 ,,	45	..	68	88	89	99,380	59,657	7,650	166,687	·80	40	
12 ,,	..	..	68	90	90	100,800	56,946	7,650	165,396	·80	40	
1 o'clock,	45	46	..	90	90	100,800	59,657	7,650	168,107	·80	40	
2 [P.M.	..	46	..	86	89	99,380	54,470	7,650	161,500	·80	40	
3 ,,	44	..	..	86	88	98,000	56,946	7,650	162,596	·80	40	
4 ,,	..	..	70	86	90	99,380	54,470	7,650	161,500	·80	40	
5 ,,	45	..	..	86	90	98,000	54,470	7,650	160,120	·80	35	
6 ,,	..	46	..	86	90	98,000	54,470	6,800	159,270	·75	40	
7 ,,	..	..	..	87	90	98,000	54,470	6,800	159,270	·75	40	
Average ..	45°	46°	68°	86°	90°	98,317	54,250	7,346	159,913	·80	40	

TABLE VII.

Synopsis of Experiment made on Saturday, January 8th, 1853, at Hetton Colliery, with the Furnace C, 9 feet wide.

Time.	Temperatures. At Bank.	Bottom of Downcast.	In Return air.	Fath. 10.	Fath. 65.	Minor Pits area 98 feet. Cubic ft. ℔ minute.	Eppleton Lane Pit, area 58 feet. Cubic ft. ℔ minute.	Portion of air through Lyon's Waste to Blossom upcast. Cubic ft. ℔ minute.	Total quan. of air passing down the downcast shafts. Cubic ft. ℔ minute.	Water Gauge in inches.	Consumption of Coals.
At 6 o'clock, A.M.	40°	45°	69°	110°	115°	112,000	59,657	8,743	180,400	1·25	
7 ,,	42	45	69	102	110	110,250	62,640	8,743	181,633	1·10	In 12 hours the Furnace consumed 7·280 lbs. of coals, which is equal to 10·11 lb. per minute; and 16,320 cubic feet of air per minute for each lb. of coal consumed. Area of Fire Grate of Furnace 9 × 4 = 36 square feet.
8 ,,	40	45	69	103	112	113.806	52,200	8,743	174,749	1·10	
9 ,,	40	45	69	111	116	112,000	50,112	10,200	172,312	1·15	
10 ,,	40	45	69	95	98	110,250	48,185	7,650	166,085	1·05	
11 ,,	43	45	69	96	99	110,250	48,185	7,650	166,085	1·10	
12 ,,	44	44	69	85	86	103,765	46.400	7,650	157,315	1·00	
1 o'clock, P.M.	50	45	69	85	90	103,765	46,400	7,650	157,815	1·00	
2 ,,	48	45	69	85	86*	103,765	44,743	7,650	156,158	1·00	
3 ,,	50	45	69	80	78	103,765	44,743	8,160	156,668	1·05	
4 ,,	45	45	69	95	90	103,765	44,743	8,743	157,251	1·00	
5 ,,	47	45	69	93	88	103,765	46,400	7,650	157,815	1·00	
6 ,,	47	45	69	85	80	103,765	46,400	6,800	156,965	1·00	
Average....	44°	45°	69°	94°	98·5	107,300	49,296	8,154	164,750	1·00	

* After this period at the 65 Fathoms Water dropped upon the Thermometer which affected the Register.

TABLE VIII.

Result of Experiments at Hetton Colliery.—Consumption of Coal.

Time.	Description of Experiment.	Temperatures. At Bank.	In Return Air.	Bottom of Downcast.	Upcast. 10 Fath.	Upcast. 65 Fath.	Cub. Ft. of Air ℔ Minute passing down the Downcast Shaft. Minor Pit.	Eppleton Jane Pit.	Portion from Elemore Pit.	Total.	Water Gauge, in Inches.	Consumption of Coals. lbs. ℔ Minute.	Consumption of Coals. Cubic Ft of Air for each lb. of Coal.
1852. 26th & 27th Nov.....	3 Furnaces	44°	68°	45°	..	130°	133,394	66,094	8,978	208,466	1·20	18·86	11·066
1853. Jan. 3rd....	37 Jets ¼ in. diam. each ..	45	68	46	86°	90	98,317	54,250	7,346	159,913	·80	25·28	6·400
Jan. 8th....	1 Furnace 9 ft.	44	69	45	94	98·5	107,300	49,296	8,154	164,750	1·00	10·11	16·320

EXPERIMENTS AT KILLINGWORTH COLLIERY.

Killingworth Colliery presented a different mode of testing the comparative powers of the Steam Jet, and Furnace, than Hetton; the boilers being at the top of the pit, and the steam being conveyed down the pit in pipes, gave an opportunity of comparing the Furnace with the Jet, having nothing but the rarefaction of the steam in the shaft to effect the experiments. And in this case the same Jets were removed from the bottom of the pit to the top, to test the relative effect at the top and bottom of the pit, and so that in the former case, no force but the impulsive force of the Jets were employed.

Figs. 2 and 3, Plate II., are elevations of the mode in which the Furnace and Jets were applied at Killingworth, *A A*, being the shaft, *B* the Furnace, and *D*, the sloping drift into the shaft. The boilers are placed about 40 yards from the pit, and the steam is conveyed down the shaft as shewn on the sketch, in pipes 10 inches in diameter, to a receiver *C*, at the bottom of the pit; *e f* representing the level of the surface. Fig. 4, is a plan of the Furnace, and shaft, and fig. 5, an elevation.

In the record of the experiments, it is stated that the experiments were tried sometimes with the Furnace doors shut and sometimes with them open. In Fig. 4, it will be seen that there is a horizontal passage, parallel with the sloping drift *D*, in which two doors at *a b* are placed—these are the doors alluded to; when the doors were shut all the air passed over the Furnace, but when open, part of this air passed along the horizontal drift into the shaft, diminishing the intensity of the Furnace in the latter case, and increasing it in the former, though adding to the resistance of the air over the Furnace.

The Killingworth pit is 14 feet diameter, but it is divided by air-tight timber brattices, or partitions, into 4 compartments, two of them being used as downcast shafts, one as an engine shaft, and the other that in which the experiments were made. Fig. 6, shews the distribution of the Jets, 29 in number, when placed at the bottom of the pit—the same Jets as used at Hetton. The Killingworth shaft is 690 feet in depth.

The same care was taken in the prosecution of those experiments as with those at Hetton Colliery.

The distance which the air travels at Killingworth is very different from that at Hetton. The division of the shaft at Killingworth used in the experiments, not being in use for Ventilating the colliery at all. The Ventilating shaft being entirely an upcast pit, 12 feet diameter, with two Furnaces. A small portion only of the workings around the shaft was used for the experiments, and regulators were put in to counteract the effect of the short run. The total distance which the air travelled was only 1,213 yards, the distance which the several currents travelled being as follows :—in a single current 160 yards, in two currents 333 yards, in three currents 533 yards, and in 4 currents 187 yards. The dimensions of the regulators are given in the experiments.

TABLE IX.

Synopsis of Experiments on Furnace and Steam Ventilation at Killingworth Colliery, November 15th, 1852.

Time.	Description of Experiment	Barometer.			Temperature.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Surface.	Bottom of Downcast.	Bottom of Upcast.	Surface.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 55 fathoms.		
Nov. 15. 8·0 P.M.	Natural Ventilation	28·85	29·53	...	50°	55°	60°	...	...	0·15	8,888
	16 Jets, 3-8ths diameter, set on at 8·14 P.M.; Steam at 40lbs. per square inch.										
8·28 ,,	Jets only.....	...	...	...	...	...	...	90°	...	...	15,605
8·52 ,,	Ditto	...	...	...	...	...	...	...	93°	...	16,570
	At 9 P.M. lighted Furnace 7 feet wide, bars 6 feet in length, about 4 feet of Fire.										
9·9 ,,	Furnace only	28·858	...	...	...	...	...	...	...	...	18,903
9·16 ,,	Ditto	...	...	...	...	...	...	...	...	...	20,334
9·46 ,,	Ditto	...	...	...	...	...	...	92	...	1·00	24,625

In these Experiments the Area of the Regulator was 3ft. 10⅞in. × 5ft. 6in., and Regulators also placed at the Splits of Air.

TABLE X.

Synopsis of Experiments on Furnace and Steam Jet Ventilation at Killingworth Colliery, November 19th, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Surface.	Bottom of Downcast.	Bottom of Upcast.	Surface.	Bottom of Downcast.	In Return Air	Upcast 10 fathoms.	Upcast 55 fathoms.		
Nov. 19th.											
5·40 P.M.	Natural Ventilation	29·325	30·08	30·03	45°	55°	..	..	73°	·15	
5·55 ,,	The air all passing through a Regulator 5 feet 6 inches, by 1 foot 2⅜ inches	..	..	..	..	..	..	95°	97	·55	8,494
6·10 ,,	Steam blowing off into Shaft; Regulator opened to 5 feet 6 inches by 2 feet	..	..	..	..	..	..	98	98	·66	16,134
	Set on Jets at 6·25 P.M.										
7·23 ,,	Jets 29 in number, ⅜ths inch diameter each, 660 feet from Bank; Steam at 40 lbs. per square inch; Furnace doors open	..	..	..	..	..	..	99	96	·62	15,783
7·26 ,,	Ditto with Furnace doors shut	..	..	..	..	..	..	..	..	·67	14,984
7·44 ,,	Regulator opened 5 feet 6 inches by 4 feet, doors still shut	..	..	..	..	.	..	..	..	..	16,259
	Opened Steam Valve further, so as to allow as much Steam to pass as the Boiler, with hard Firing could supply; Furnace Doors shut	..	..	..	..	..	..	102	..	1·10	25,164
8·32 ,,	With Furnace Doors opened	29·332	..	..	..	..	..	..	99	1·05	24,164
	⅜th Jets taken off at 8·50, and ⅛th Jets put on; Steam applied at 9·20 P.M.										
9·57 ,,	With 29 Jets, ⅜ths diameter; Furnace Doors shut	..	..	..	..	..	..	..	99	0·80	23,168
	Ditto ditto with Doors open	..	..	..	..	..	..	92	..	..	24,143
	Jets taken off and Steam made to blow into Shaft without force (5 inches diameter pipe); Doors open	..	..	..	..	..	..	..	99	0·70	20,708
	Lighted Furnace at 10·50 P.M.										
11·21 ,,	Furnace, 7 feet by 4 feet, with Doors shut	..	..	..	..	..	61°	100	142	1·00	25,328
12 ,,	Ditto ditto	..	..	..	..	..	..	133	..	..	26,774
12·4 ,,	Ditto ditto Doors opened	..	..	..	48°	..	..	..	150	0·85	25,794

TABLE XI.

Synopsis of Experiments on Furnace and Steam Jet Ventilation at Killingworth Colliery, Nov. 19th and 29th, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Surface.	Bottom of Downcast.	Bottom of Upcast.	Surface.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 55 fathoms.		
Nov. 20th.	Furnace on all night from 12·4 A.M., last Experiment November 19th to 8·35 November 20th	29·175	...	...	43°	...	...	...	141°		
9·5 A.M.	Ditto	...	29·83	29·84	...	55°	...	...	...	·78	
9·15 „	Ditto	...	...	...	...	...	...	125°	...	·85	
9·30 „	Furnace on, Blazer down, and Doors shut	...	...	...	...	...	...	...	...	...	23·102
9·56 „	Ditto Blazer up	...	...	...	...	...	60·5	...	145	·80	24·220
9·59 „	Ditto Blazer down	...	...	...	...	...	...	122	...	...	23·359
	Jets set on at 10·25 A.M.										
	29 Jets $\frac{3}{16}$th inch diameter each, with Furnace doors shut	...	...	...	...	...	...	...	152	1·30	
	Ditto with Furnace doors open	...	...	...	...	...	...	...	...	1·10	
10·35 „	Doors partially opened so as to keep the intensity of Fire about the same as when the Furnance above was on with Blazer up	...	...	...	...	...	...	...	...	1·15	29·752
10·58 „	Jets and Furnace on	...	...	...	...	...	...	144	155	...	
11·49 „	Ditto	...	...	...	...	...	...	...	154	...	31·070
12·6 „	Ditto	...	...	...	...	...	...	151	...	1·2	31·661
	Jets taken off at 12·15 A.M.										
12·25 „	Jets off and Furnace on	...	...	...	...	...	...	...	150	·85	
12·39 „	Furnace only; Doors closed	29·215	...	...	43½	58	...	130	...	...	24·583

TABLE XII.

Synopsis of Experiments made on Furnace and Steam Jet Ventilation at Killingworth Colliery, December 2nd, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.					Water Gauge in inches.	Quantity of Air in cubic feet per minute.
		Surface.	Bottom of Downcast.	Bottom of Upcast.	Surface.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 55 fathoms.		
Dec. 2nd.											
6·45 P.M.	Shaft cooled down, Natural Ventilation, with Furnace Doors shut	29·429	...	...	40°	52°25′	60°	71°	72°	·26	13·527
7·5 ,,	Ditto, Furnace Doors open	...	...	...	...	...	...	71	...	·25	14·904
	Steam set on to blow into Shaft at 8 P.M.										
8·26 ,,	Steam only; Furnace Doors open	...	...	...	...	...	...	103	112	·60	32·055
8·31 ,,	Ditto; Furnace Door shut	...	...	...	...	53	...	105	112	·58	29·250
	Jets set on at 9·40 P.M.										
	29 Jets, $\frac{5}{8}$-inch diameter each, blowing through Cylinders 6 feet long and 11 inches diameter										
9·40 ,,	29 Jets, $\frac{5}{8}$-inch diameter each	29·455	...	...	...	...	...	100	109		
9·59 ,,	Jets, Furnace Doors open, Steam at 38lbs. to 40lbs.	...	...	...	...	...	...	103	104	·61	34·314
10·48 ,,	Jets in Cylinders, Doors open	...	...	...	...	...	...	104	106	·65	35·523
	Cylinders taken off Jets at 11·50	...	...	...	...	...	...	108	109		
12·7 A.M.	Jets without Cylinders, Doors at Furnace open	29·528	...	...	...	...	...	100	108	...	35·347
	Lighted Furnace at 1 A.M.										
1·7 ,,	Furnace only, Furnace Doors open	...	...	...	...	...	...	122	125	·6	
1·38 ,,	Ditto, with Furnace Doors shut	...	...	...	...	...	...	160	168	1·1	36·732
2·29 ,,	Ditto, Blazer down (Doors partially opened)	...	...	...	...	...	...	154	162	...	38·360
2·32 ,,	Ditto, ditto, Doors 1 foot open	...	...	...	...	...	...	...	...	...	38·677
2·35 ,,	Ditto, Doors wide open	...	...	...	...	...	...	134	145	...	38·360
	Jets set on with Furnce.										
	Jets and Furnace	...	...	...	...	...	...	155	162		
3·23 ,,	Furnace Doors open	...	...	...	...	...	...	...	...	...	44·150
		...	...	...	...	...	...	195	205		

TABLE XIII.

Synopsis of Experiments on Furnace and Steam Jet Ventilation at Killingworth Colliery, December 4th, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.					Water Gauge in inches.	Quantity of Air in cubic feet per minute
		Surface.	Bottom of Downcast.	Bottom of Upcast.	Surface.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 55 fathoms.		
Dec. 4th. 11·8 A.M.	Shaft cooled down	29·505	...	...	44°	54°	...	...	65°	·25	9·176
	Steam set on to blow into Shaft at 11·20 A.M.										
11·50 ,,	Steam only; Furnace Doors shut	...	...	...	...	...	60°	...	88	·55	28·888
	Set on Jets at 12 A.M.; 40 lbs. per square inch. 29 Jets, $\frac{3}{8}$-inch diameter each; 2,83 cubic feet of Water evaporated per minute.										
12·18 ,,	Jets only; with Furnace Doors open	...	...	...	...	...	...	...	101	·70	32·500
	Jets taken off and Furnace lighted 12·40 P.M.										
12·54 ,,	Furnace only; with Blazer up and Doors shut	...	...	...	...	...	...	...	135	·87	36·392
1·21 ,,	Ditto, and Doors open	...	...	...	...	...	...	...	137	·95	37·741
1·51 ,,	Jets and Furnace; Doors open	...	...	...	...	...	...	...	164	1·25	44·570

TABLE XIV.

Synopsis of Experiments on the Furnace and Steam Jet at Killingworth Colliery, December 10th, 1852.

Time.	Description of Experiment.	Barometer.			Temperature.				Water Gauge.	Quantity of Air in cubic feet per minute
		Bank.	Bottom of Downcast.	Bottom of Upcast.	Bank.	Bottom of Downcast.	In Return Air.	Upcast Shaft at 55 faths.		
Dec. 10. 4·30 P.M.	Natural Ventilation; Furnace doors opened	...	...	...	49°·25	53°·75	62°·25	...	·10	11·249
	Jets set on at Bank at 5·40 P.M.; 29 Jets $\frac{3}{8}$th inch diameter each; Steam at 40lb per square inch. Evaporation of Water 2·83 cubic foot per minute.									
6·30 ,,	Jets only; Furnace doors open	...	...	...	...	...	60	77°	.35	23·018
6·47 ,,	Ditto; Furnace doors shut	...	...	...	...	...	...	78	...	21·467
	Furnace lighted at 7·40 P.M., and Jets shut off.									
8·1 ,,	Furnace only; Furnace doors shut	...	...	...	...	...	...	138	...	33·281
8·15 ,,	Ditto Ditto	...	...	...	...	...	...	132	·90	33·428
8·25 ,,	Ditto Ditto	...	...	...	...	...	...	...	...	32·880
	Jets set on, in addition to Furnace, at 8·30 P.M.									
9·21 ,,	Jets and Furnace; Furnace doors shut	29·06	...	...	...	...	...	161	1·025	37·707
9·30 ,,	Ditto ..... Ditto	...	...	...	...	...	...	152		

TYNE MAIN COLLIERY EXPERIMENTS.

The experiments at Tyne Main were made with the Furnace, and with the Steam Jets at the top of the pit. I have previously stated the reasons why these experiments were made, viz :—that the increased area of the shaft, near the top, admitted of the Jets being placed within the pit, the area within the cylinders, (when the interstices were closed up,) being nearly equal to the area of the shaft generally.

Fig. 7, plate II., shews the mode in which the Furnaces were applied at this colliery ; *A*, being the shaft, *B B*, the Furnaces, and *D*, the sloping drift to the shaft. Fig. 9, is an elevation of the two Furnaces, and Fig. 10, a plan of the same. Fig. 8, shews the Jets placed at the top of the pit, *e f*, being the level of the surface. The boilers in this case, being about 30 yards from the top of the pit, and the steam conveyed from thence to the Jets, with a pipe 6 inches in diameter. Fig. 11, shews the disposition of the Jets within the area of the shaft, 61 in number, the same Jets as were applied at Hetton and Killingworth, $\frac{5}{16}$ths and $\frac{3}{8}$ths of an inch in diameter.

The workings of this colliery are not very extensive. There has been about 50 acres of coal entirely taken away, the space forming the goaf of the colliery. 158 acres of coal has been partially worked, about one-third excavated and two-thirds remaining in pillars. There is, therefore, a space of 56 acres of excavation, and 50 acres of goaf to ventilate $5\frac{1}{2}$ feet in height.

The total length of air courses is as follows :—

No. 1, split 40,000 cub. ft. ℔ min.			No. 2, split, 66,000 cub. ft. ℔ min.		
No. of Currents.	Distance travelled in feet.	Quantity of Air in cubic feet ℔ minute.	No. of Currents.	Distance travelled in feet.	Quantity of Air in cubic feet ℔ minute.
1, 2, 3...	396	40,000	4, 5, 6...	792	66,000
3	1,782	15,000	6	5,950	26,000
1, 2.....	7,392	25,000	4, 5	1,716	40,000
1	1,716	12,500	4	2,442	20,000
2	3,498	12,500	5	1,980	20,000
1, 2.....	2,112	25,000	4, 5, 6...	792	66,000
1, 2, 3...	396	40,000			

The following tables are the experiments made :—

TABLE XV.

Synopsis of Experiments on the Furnace and Steam Jet at Tyne Main Colliery, 14th January, 1853, there being two Boilers; each 30 feet long, and 6 feet diameter, with 61 Jets, 28 of which were $\frac{3}{8}$th inch diameter, and 33th $\frac{3}{16}$, inch diameter, Cylinders 6 feet long, 11 inches diameter.

Time.	Description of Experiment.	Temperature.					Pressure of Steam, lb. per square inch.	Water Gauge.		Quantity of Air, cubic ft. per minute	Remarks.
		Bank.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 65 fathoms.		East Door.	West Door.		
								Inch.	Inch.		
11·23 A.M.	Natural Ventilation.....	36°	42°	63°	62°	61°	...	·2	·2	34,955	Furnace put out 10 P.M., January 13th, and remained out until 1·20 P.M., January 14th.
	Jets set on at 11·40, with Cylinders 6 feet long, 11 inches diameter	...	...	...	...	...	35	...	...	...	
12·30 ,,	Jets alone	...	...	...	62	60	22·5	·3	·325	47,407	
1·15 P.M.	Ditto	...	42	...	62	60	22·5	...	...	46,834	Jets on 1H. 40M., consumed 3,548 lbs. of coal to evaporate 192·5 cub. feet of water, is 1,92 cubic feet of water, and 35·84 lbs. of coal per minute.
	Jets taken off; Furnace lighted at 1·20 P.M.										
1·30 ,,	Furnace only.....	38	...	63	102	105	...	·775	·9	84,280	
2· ,,	Ditto	...	...	...	144	138	...	·875	1·	87,919	
2·30 ,,	Ditto	...	42	...	158	155	...	·9	1·	101,137	
3· ,,	Ditto	...	...	63	160	144	...	·9	1·	102,500	
					Upcast 35 Fas.	Upcast 75 Fas.					
3·30 ,,	Ditto	...	42	...	195	193	...	...	...	99,805	
	Jet set on with Furnace at 3·30 P.M.										
4· ,,	Jets and Furnace	40	...	63	198	260	30	1·2	1·3	108,300	Jets on 30 min., evaporated 119 cub. ft. of water=3·96 cub. ft. per min.; water being low in the Boilers, and no feed.

* Water falling on the Thermometers.

TABLE XVI.

Synopsis of Experiments on the Furnace and Steam Jet at Tyne Main Colliery, 15th January, 1853; there being two Boilers, each 30 feet long and 6 feet in diameter, with 61 Jets, each $\frac{5}{16}$th of an inch in diameter; Area 1·6843 inches; within Cylinders, 6 feet long and 11 inches diameter; Area = 40·258 feet.

Time.	Description of Experiments.	Temperature.					Pressure of Steam, lb. per square inch.	Water Gauge.		Quantity of Air, cub. ft. per minute.	Remarks.
		Bank.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 65 fathoms.		East Door.	West Door.		
								inch.	inch.		
	Jets set on at 8·45 A.M.	..	..	..	..	..	..	..	..	..	Furnace put out at 8 P.M., January 14th, and remained out until 12·40 A.M., January 15th.
10·20 A.M.	Jets alone	..	43°	..	..	..	40	·3	·4	49,254	Jets on 2h. 55m.; Coals consumed, 3,584lbs. = 20·48lbs. per minute; Water evaporated, 318·5 cubic feet = 1·82 cubic feet per minute; is 11·2lbs. for each cubic feet of Water evaporated, and 2,420 cub. feet of Air for each lb. of Coal consumed.
11· ,,	Ditto	..	..	63°	64°	63°	40	·3	·4	49,574	
11·30 ,,	Ditto	45°	..		63	61	40	·3	·375	49,574	
	Jets taken off at 11·40 A.M.										
12· ,,	Natural Ventilation	..	..	63	64	62	..	·2	·2	36,564	
12·30 P.M.	Ditto		43	..	65	62	..	·2	·2	37,182	
	Furnace lighted at 12·40 P.M.										
1· ,,	Furnace alone	45	..	..	183	180	..	·8	·9	94,815	
1·30 ,,	Ditto	..	..	63	189	223	..	1·05	1·15	94,815	
2· ,,	Ditto		..	..	207	262	..	1·05	1·18	99,805	
2·30 ,,	Ditto	..	..	..	..	..	..	1·1	1·2	102,503	
	Jets set on with Furnace at 2·40 P.M.										
3· ,,	Furnace and Jets	45	..	63	210	272	40	1·15	1·25	105,350	Jets on 1 hour; Coals consumed, 1,792lbs.; Water evaporated, 133 cubic feet, or 2·21 per minute.
3·30 ,,	Ditto	..	43	..	..	..	40	1·15	1·25	106,830	

TABLE XVII.

Synopsis of Experiment on the Furnace at Tyne Main Colliery, January 20th, 1853.

Time.	Temperature. Bank.	Bottom of Downcast.	In Return Air.	Upcast 10 fathoms.	Upcast 65 fathoms.	Water Gauge. East Door.	West Door.	Quantity of Air in cubic feet per minute.	Remarks.
						Inch	Inch		
A.M. 6 o'clock	49°	...	...	105°	95°	6	·65	68,956	
7 ,,	...	52°	...	130	100	·75	·80	88,200	The quantity of coals consumed by the two Furnaces, in 12 hours, was 12,070lbs., which is equal to 16·76lbs. per minute, and 6,080 cubic feet per minute for each lb. of coal consumed.
8 ,,	...	...	63°	175	...	·95	1·	99,805	
9 ,,	50	...	...	163	...	·95	1·	99,805	
10 ,,	...	52	...	176	...	·95	1·	99,805	
11 ,,	...	...	63	170	...	·90	·95	99,805	
12 ,,	50	...	...	174	...	·90	·90	102,500	
P.M. 1 o'clock	...	50	...	161	...	90	·90	103,907	
2 ,,	...	...	63	162	...	·90	·90	105,350	
3 ,,	49·5	...	...	149	...	·90	·90	103,907	
3·30 ,,	...	...	...	...	159	...	...	...	
4 ,,	...	50	...	165	...	·95	95	109,933	
4·30 ,,	...	...	...	...	160	...	...	...	
5 ,,	...	...	63	159	...	·90	·90	101,113	
5·30 ,,	...	...	...	...	151	...	...	...	
6 ,,	49·5	...	...	157	...	90	·90	108,360	
Average...	49·75°	51°	63°	161°·75	145° 5	·904	·925	101,876	

TABLE XVIII.

Synopsis of Experiment at Tyne Main Colliery, on the Steam Jets, 61 in number, $\frac{3}{16}$ths diameter each, without the cylinders, January 28, 1853.

Time.	Description of Experiment.	Temperature. Bank.	Bottom of Downcast.	In Return Air.	Upcast 30 fathms.	Quan. of Air. Cubic Feet per min.	Water Gauge. East Door.	West Door.	Press. of Steam. lb. per sq. inch.	Consumption of Coals, &c.
10·30 A.M.	Nat. Ventilation ..	32°	..	62.°5	65°	39,506	·3	·3	..	Furnace put out at 4 P.M., January 27th, & remained out until the Experiments were finished.
11 ,,	Ditto	..	40°	62·5	65	34,506	·3	·3	..	
	Jets set on at 11·15 A.M.	..	..	..	..	..	..	..	..	2,558 lbs. of coals consumed in two hours, and 248·5 cub. ft. of water evapd., which in two hours, is 2·07 cub. ft. per min., =10·2 lbs. of coal to a cubic ft. of water, and 2,223 cub. ft. of air for each lb. of coal consumed.
11·30 ,,	Jets alone	35	..	62·5	68	47,407	·38	·38	40	
12 ,,	Ditto	..	40	..	63	47,407	·38	·38	40	
12·30 P.M.	Ditto	36	..	62·5	62	47,407	·38	·38	40	
1 ,,	..... Ditto	..	40	62·5	62	47,407	·38	·38	40	
	Average.....	35.°5	40	62.°5	63.°75	47,407	·38	·38	40	

NORWOOD COLLIERY EXPERIMENTS.

The experiments at Norwood Colliery were made by Mr. Greenwell, for the purpose of testing the comparative powers of the Furnace, and Steam Jet,—the area of the Furnace bars being precisely the same as the area of the fire bars of the boiler; and, likewise, for the purpose of testing their comparative merits in shafts of small depths.

Figs. 1 and 2, Plate III., shews the manner in which the Jets were applied, *A A*, being the shaft. The shaft was divided by an air-tight timber partition or brattice, shewn at *c d*, Fig. 1, and *d d*, Fig. 2, the air passing down the side *A*, and returning up the opposite side. *a a a*, Fig. 1, shews the steam pipe leading from the boiler to the Jets, which were placed at *b*, 180 feet from the top of the pit; and *e e e*, Fig. 2, shews the distribution of the Jets in the shaft. The Furnace is shewn at *g*, Fig. 1, at the bottom of the pit, and 252 feet from the surface, *B*, Fig. 3, being an elevation.

The shaft is 11 feet diameter—the area of the downcast being 73,766 feet, and the upcast 18,323 feet; the brattice occupying the remainder of the area. The steam pipe *a a a*, was 3 inches diameter, the boiler with which it was connected being 28 feet long and $6\frac{1}{2}$ feet diameter; the number of Jets were 26; $\frac{3}{16}$ths of an inch diameter each. The steam was kept at 33·8 lbs. per square inch during the experiments. The area of fire grates of Furnace and engine fire was 5 feet by 4 feet each.

The following Table will shew the result of the experiments :—

TABLE XIX.

Synopsis of Experiments on Furnace and Steam Jet Ventilation at Norwood Colliery, August, 1852.

Time.	Description of Experiments.	Barometer at Bank.	Temperature.				Coals Consumed in 24 Houss.	Water Gauge in inches.	Cubic feet of Air per minute.	Water evaporated in 24 hours.
			Bank.	Bottom of Downcast.	From Surface of Upcast.					
					21 fath.	15 fath.				
Aug. 10	Jets alone, Bord end Doors open...	...	...	...	...	...	lbs. 6955·2	...	9,690	
,, 12	Jets alone, Bord end Doors closed	29·16	59°	64°	...	98°	6955·2	·26	6,000	
	Steam alone, do. ...	...	...	...	...	...	...	...	2,880	
	Furnace alone, do ..	...	...	...	...	...	...	...	7,200	
	Jets alone, Bord end Doors open	...	...	64	...	98	7324·8	·20	8,000	
	Furnace alone, do....	...	...	64	94°	...	...	·30	8,472	
	Furnace and Jets, do.	...	...	...	...	...	...	·40	9,000	
,, 13	Furnace alone, Bord end Doors closed	...	...	64	100	...	967·68	·30	8,000	
	Furnace alone, Bord end Doors open ...	...	...	64	100	...		·40	9,600	
	Furnace and Jets, Bord end Doors open.....	...	...	64	...	112	...	·50	11,064	

We shall now investigate the practical results of the foregoing experiments. In the first place, however, it will be necessary to determine the resistances opposed to the moving powers of the Furnace and Steam Jet, in order to compare their efficient performances in producing Ventilation.

I have previously stated, that, I employed the Water Gauge to measure the power required to force the current of air around the workings of the mine, and I have described the mode in which this was taken. In the prosecution of these experiments, the amount of Water Gauge exhibited, when the current was moved at different rates of velocity, was, accurately taken ; and the foregoing Tables will show the Water Gauge in a great variety of cases, and at very various velocities of current.

The following Tables are the result of these experiments :—

TABLE XX.

Experiments made to determine the Power required to produce different Velocities of Currents of Air in Coal Mines, ascertained by the Height of Water Gauge.

HETTON COLLIERY.

DESCRIPTION OF POWER.	Date of Experiments.	Time of Experiments.	Water Gauge inches.	Quantity of Air in cubic feet per minute.	OBSERVATIONS.
	1852.				
3 Boiler Fires, and 3 Furnaces.	Oct. 12	7· 0 P.M.	1·4	198,261	
3 Furnaces	,,	9· 0 P.M.	1·3	187,000	
3 Boiler Fires, and 3 Furnaces.	Oct. 29	7·50 P.M.	1·5	201,274	
3 Furnaces	,,	8·15 ,,	1·55	205,636	
Natural Ventilation	Oct. 30	6·30 A.M.	·6	130,890	
2 Boiler Fires	,,	9· 0 A.M.	·6	139,176	
2 Boiler Fires, Jets, and 3 Furnaces	,,	6· 0 ,,	1·5	207,093	
Natural Ventilation	Oct. 31	6·15 A.M.	·35	99,414	
Furnaces	,,	9· 0 ,,	1·35	201,960	
3 Boiler Fires, and 3 Furnaces.	Nov. 3	7·15 P.M.	1·4	208,443	
Do.	,,	9· 0 ,,	1·5	212,907	
Natural Ventilation	Nov. 13	8·30 A.M.	·5	123,463	
2 Boiler Fires	,,	10·30 ,,	·6	132,053	
Do. and Steam	,,	11·30 ,,	·6	139,847	
2 Boiler Fires, and Jets	,,	12·30 ,,	·8625	164,376	
Do.	,,	1·30 P.M.	·855	163,614	
Natural Ventilation	,,	3·30 ,,	·55	127,145	
3 Furnaces	,,	4·30 ,,	1·75	211,193	
Do.	,,	5·30 ,,	1·95	225,176	
3 Furnaces, and 2 Boiler Fires.	,,	6· 0 ,,	2·0	229,918	
3 Furnaces, and 2 Boiler Fires and Jets	,,	6·26 ,,	2·05	234,118	
Natural Ventilation	Dec. 11	8· 0 A.M.		117,908	
2 Boiler Fires	,,	11· 0 ,,	·4	121,464	
2 Boiler Fires, and Steam	,,	12· 0 ,,	·55	129,369	
2 Do. and Jets	,,	3·30 ,,	·7	146,010	
1 Furnace	,,	4·16 ,,	·8	166,826	
2 Boiler Fires, Jets, and 1 Furnace	,,	5·55 ,,	1·17	194,075	

TABLE XXI.

Experiments on Water Gauge continued.

KILLINGWORTH COLLIERY.

DESCRIPTION OF POWER.	Date of Experiments.	Time of Experiments.	Water Gauge in inches.	Quantity of air in cubic feet per minute.	OBSERVATIONS.
Natural Ventilation ...	Nov.15	8· 0 P.M.	·15	8,888	Regulators 3ft. 11in.
Furnace ...	,,	9· 0 ,,	1·	24,625	× 5ft. 6in.
Natural Ventilation ...	Nov.19	5·40 A.M.	·15	8,494	Reg. 5ft. 6in. × 2ft.
Steam only ...	,,	6·14 ,,	·66	16,134	Doors open.
Jets, $\frac{3}{8}$ths ...	,,	7·17 ,,	·62	15,778	Doors open.
Do. ...	,,	7·30 ,,	·67	14,984	Doors shut.
Do. ...	,,	7·40 ,,	...	16,259	Do. Regulator opened to 5ft. 6in. × 4ft.
Do. ...	,,	8·10 ,,	1·10	24,164	Steam valve opened; doors still shut.
Jets taken off ...	,,	8·30 ,,	1·05	24,164	Furnace doors open.
Jets, $\frac{3}{16}$lb. ...	,,	9·50 ,,	·80	14,917	Do. shut.
Do. ...	,,	10· 2 ,,	...	15,390	Do. open.
Steam only ...	,,	10·17 ,,	·70	13,706	Do. do.
Furnace ...	,,	11·21 ,,	1·	25,328	Do. shut.
Do. ...	,,	12· 0 ,,	...	26,775	Do. do.
Do. ...	,,	12· 5 ,,	·85	25,794	Doors opened.
Do. ...	Nov.20	9·46 A.M.	·80	24,220	Reg. 5ft. 6in × 4ft.
Furnace, and Jets ...	,,	11·49 ,,	1·15	31,070	Do.
Furnace ...	,,	12 39 ,,	·85	24,588	Do.
Natural Ventilation ...	Dec. 2	6·40 A.M.	·26	13,526	Reg. 5ft. 6in. × 4ft.
Steam only ...	,,	8·26 ,,	·60	32,055	Do.
Jets, Cylinders on ...	,,	9·59 ,,	·65	35,454	Do.
Do off ...	,,	12· 3 P.M.	...	35,454	Do.
Furnace ...	,,	1·35 ,,	1·1	36,731	Do.
Do. ...	,,	2·26 ,,		38,677	Do.
Furnace, and Jets ...	,,	3·23 ,,	·96	44,150	Do.
Natural Ventilation ...	Dec. 4	10·45 ,,	·25	9,176	Reg. 5ft. 6in. × 4ft.
Steam ...	,,	11·50 ,,	·55	28,888	
Jets ...	,,	12·15 ,,	·70	32,500	
Furnace ...	,,	12·50 ,,	·87	36,392	
Do. ...	,,	1·20 A.M.	·95	37,741	
Furnace, and Jets ...	,,	1·50 ,,	1·25	44,570	

TABLE XXII.

Experiments on Water Gauge continued.

TYNE MAIN COLLIERY.

DESCRIPTION OF POWER.	Date of Experiments.	Time of Experiments.	Water Gauge in inches.	Quantity of air in cubic feet per minute.	OBSERVATIONS.
	1853.				
Natural Ventilation ...	Jan.14	11·23 A.M.	·2	34,955	
Jets ...	,,	1·15 P.M.	·325	47,407	
2 Furnaces ...	,,	3· ,,	1·	102,500	
2 Furnaces, and Jets ...	,,	4· ,,	1·3	108,300	
Jets ...	Jan.15	11·30 A.M.	·4	49,574	
Natural Ventilation ...	,,	12·30 P.M.	·2	36,873	
2 Furnaces ...	,,	2·30 ,,	1·2	102,503	
2 Furnaces, and Jets ...	,,	3·30 ,,	1·25	106,830	

I shall take the experiments in Table XIX., made on the 13th November, 1852, as an example at Hetton Colliery ; and in order to more clearly shew the quantities of air produced with the different heights of Water Gauge, I have made a Diagram showing the curve of such increase, corresponding with the different heights of Water Gauge, which is shewn in Plate IV. I have taken the experiments at Killingworth on the 4th December, as an illustration of the effect of the Water Gauge at that colliery, the length of the current being very small compared with that of Hetton, and where the velocity of the air was obstructed, by having to pass through a regulator 22 feet area. The Diagram, exhibiting the curve of the different heights of Water Gauge, is shown in Plate V. ; and I have taken the experiment of January 15, 1853, as the result of the Water Gauge in Tyne Main Colliery for the same object, Plate VI., showing the curve.

On an examination of these Diagrams, it will be seen, that the quantities of air produced does not materially vary from the square roots of the height of Water Gauge, or power employed, to produce those quantities ; the dotted lines shewing the line according to the square roots, and the black line the curve of the quantities actually produced.

The power required to force the air around the workings, is not however the only motive power required in the Ventilation of a Coal Mine. The Water Gauge in these experiments is the power which is required to force the current from the one side of the doors *a*, Fig. 12, Plate II., from the down-cast shaft *A*, around the workings to the other side of the doors in its return to the Furnace *F*. We have in addition to this, the power required to force the current over the Furnace *F*., and up the upcast shaft *B*.

This would appear of little moment, looking at the distance which the air has to travel from the side of the doors at *a*, Fig. 12, to the shaft *B*, and so to the surface, compared with the extent of air courses, as shewn on the sketch in the Plate. But we shall see that this distance absorbs a considerable portion of the ventilating power, and presents an important element in the theory and practice of mine ventilation.

The air has first of all to pass over the Furnace ; and in order to produce the requisite vigour or intensity of combustion, and to consume the fuel as completely as practicable, the air is thrown upon the fire with

great force, the passage over the Furnace being contracted for that purpose; this presents considerable resistance to the free motion of the current. The air is now heated and expanded in bulk, its velocity is correspondingly increased, and as has already been demonstrated, the resistance being as the square of the velocity, the increased velocity presents increased resistance. It may be, that in practice the shaft may be made of a correspondingly increased area, so that the additional resistance due to the increased velocity of the current by its expansion is counteracted; but our intention being, to ascertain the relative resistances at different rates of velocities induced by the increased temperature of the air, the experiments have of course being made in shafts of the same areas.

In order to shew the curve resulting from the resistances over the Furnace and up the shaft, at the different velocities, I have made Diagrams similar to those exhibiting the power required to force the air around the workings, which Diagrams are shewn in Plates VII., VIII., and IX.

The first column in these Diagrams shews the temperature of the air passing down the downcast shaft—the weight of which per square foot of area of shaft will be seen in Table III.,—the second column is the mean temperature of the air passing up the upcast shaft, the weight or pressure of which per square foot area can be similarly ascertained,—the third column is the velocity of the air in passing down the downcast,—the fourth column shewing the increased velocity in the upcast by the increased temperatures,—the fifth column is the quantity of air passing round the mine in cubic feet per minute, measured by powder smoke in the downcast shaft,—the sixth column is the amount of Water Gauge, or power required, in lbs. per square foot of area of shaft, to force the air around the workings;—and, the seventh column shews the power required to force the air over the Furnace and up the upcast shaft; being obtained by deducting the amount of Water Gauge in the sixth column, from the difference between the weight of the column of air in the downcast, and upcast shafts: thus, A being the moving power or weight of column of air in the downcast,—B the weight of column in upcast,—C the Water Gauge,—and C' the power required to force the air over the furnace and up the upcast.

Then, $A = BCC'$ and $C' = A—BC$.

An examination of these Diagrams will shew, the comparative increase of power required to force the air up the shaft, and that required

to force the air around the workings; especially in the case of Tyne Main, where the velocity of the air through the cylinders of the Steam Jet was excessively great, nearly 64·5 feet per second, or 3870 feet per minute. The power expended in forcing the air over the furnace and up the shaft, being in this case greater than what was required to force the air around the workings, as will be seen on diagram, Plate IX.

I shall not pursue this part of the enquiry further at present, as the experiments when closely examined will, I trust, give all the information requisite for the object of this paper. This part of the subject is, however, of such great importance in the theory, practice, economy, and efficiency of Mine Ventilation; that I presume the Institute will not rest satisfied until it has made itself master of all the information requisite to a complete solution of the entire subject.

It is now necessary, before proceeding further, to notice an impression of some consequence, which was strongly urged before the Committee of the Lords in 1849; and which, if it had not been made the subject of investigation in this enquiry, might have received confirmation, and if so, would have produced an erroneous conclusion of the facts as regards Coal Mine Ventilation. I allude to the supposition, that the current of air in a mine requires some considerable period of time to be put in motion, or to be made to acquire its maximum velocity; and when in motion that its momentum causes it to retain its velocity some considerable time after the impulsive power is withdrawn.

The following is one of many experiments made to determine this. In the experiment of Nov. 13th, at Hetton Colliery, the Furnaces were put out, the Engine Fires were damped, and the temperature of the air in the upcast reduced to 74°; and the quantity of air passing through the workings reduced to 80·182 cubic feet per minute. The Furnaces were then lighted. The velocity of the current of air passing towards the Furnace *C*, Fig. 3, Plate I., was measured by one of Biram's most improved 12-inch Anemometers within 50 yards of the Furnace.

The time during which the vernier of the Anemometer marked 1000 feet was correctly noted, and the following was the result :—

TIME. H.	M.	S.		H.	M.	S.
3	48	47	Commenced experiment, Temp. 75°.			
3	50	50				
3	52	53				
3	54	52	Four revolutions of anemometer = 4,000 feet, in	0	8	3
3	56	55				
			Applied the fire to the furnaces at 4 h. 3 min.			
4	8	55	Commenced experiment.			
4	9	57				
4	10	57				
4	11	58	Four revolutions = 4,000 feet, in	0	4	3
4	12	58				
4	13	55				
4	14	52				
4	15	50	Four revolutions = 4,000 feet, in	0	3	48
4	16	46				
4	17	42				
4	18	39				
4	19	34	Four revolutions = 4,000 feet, in	0	3	34½
4	20	30½				

The Water Gauge also shewed how rapidly the current increased in velocity :—

H.	M.	S.	INCHES.
4	0	0	·45
4	3	0	·70
4	5	0	·90
4	6	0	1·
4	7	0	1·30
4	8	0	1·40
4	9	0	1·45
4	10	0	1·50
4	11	0	1·6
4	23	0	1·75

These results took place, the measurement of the air being taken near the Furnace, *C*, Plate I.; and the Water Gauge applied at the doors between the downcast, or air entering the workings, and the air returning from the workings, as at the doors, *a*, Fig. 1, Plate II. The quantity of air entering the mine was, however, measured every half hour at the respective downcast shafts, and the following was the result :—

Time. H.	M.	E. and W. Minor. C. F., per min.	Eppleton. C. F., per min.	Elemore. C. F., per min.	Total. C. F., per min.
3	30	80·182	46·400	5·563	127·145
4	30	138·353	62·640	10·200	211·193

The distance which the currents of air had to traverse between the respective downcast and upcast shafts, will be seen by an inspection of the Table of the Hetton Ventilation—Table I. Appendix.

The same comparative result took place on the application of the Steam Jets, 37 in number, $\frac{1}{4}$th inch diameter. Steam, 40lbs. per square inch.

STEAM BLOWING INTO FURNACE DRIFTS.

H.	M.	S.	
11	50	25	Commenced experiment.
11	52	25	Three revolutions in 6 min., nearly 1,000 feet in 2 min. Jets set on.
11	54	30	
11	56	24	
11	58	1	Four revolutions in 6 min. 32 sec., or 1,000 feet in 1 min. 38 sec.
11	59	35	
12	1	11	
12	2	45	
12	4	33	

The effect, as shewn by these experiments, and which was corroborated by several others, which it is not necessary to give here; shews, that it requires only a very short time indeed to put the entire current of a coal mine into its maximum velocity.

I shall now proceed to ascertain the relative power and efficiency of the different modes of Ventilation, as elicited by the preceding experiments.

The following Tables shew the general result of the experiments at Hetton, Killingworth, Tyne Main, and Norwood Collieries.

TABLE XXII.

General Result of the Experiments at Hetton Colliery.

Date.	Natural Ventilation.		Engine Fires.		Engine Fires and Steam.		Engine Fires, Steam, and Jets.		Three Furnaces.		Three Furnaces, Engine Fires, and Steam.		Three Furnaces, Engine Fires, Steam, and Jets.	
	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.
1852.														
October 12th	..	..	..	..	..	..	..	..	126°6′	187,580	148°7′	198,261		
,, 29th	..	..	..	..	..	..	..	..		..	180	205,615		
,, ,,	..	..	..	..	..	..	..	..		..	180	201,274	180°	205,636
,, 30th	85°	130,890	..	..	98°	139,176	105°	149,284		..			164	207,093
,, ,,	..	..	..	..	..	..	105	150,873	..	..	..	..		
,, 31st	85	104,414	..	..	..	..	..	..	167	201,960				
November 3rd	..	..	..	..	..	..	..	..	..	..	168	208,443	180	212,907
,, 13th	80	123,463	89°	132,053	91	139,847	94	164,376	178	211,193				
,, ,,	68	127,145	..	..	..	..	..	..	211	225,176	226	229,918	229	234,118
	80°	121,478	89°	132,053	94°5′	139,512	101°5′	166,133	176°6′	206,477	189°5′	208,702	188°	214,938
									One Furnace.				One Furnace and Jets.	
December 11th	73°	117,908	81°	121,464	82°	129,569	88°7′	146,010	95°	166,826	..	..	124°	194,075

TABLE XXIII.

General Result of the Experiments at Killingworth Colliery.

Date.	Natural Ventilation.		Steam Alone.		Jets and Steam.		Furnace alone.		Furnace, Jets, and Steam.		
	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	
1852. Nov. 15th.	...	8,888	...	...	90°	16,570	92°	24,625	...	...	Regulator 3ft. 10⅞in. × 5ft. 6in. also other regulators in.
,, 19th.	95°	8,494	98°	16,134	90	16,259	...	...	...	...	Do. 1ft. 2⅔in. × 5ft. 6in. other regula. out.
,, ,,	...	...	102	20,708	102	24,164	133	26,774	...	...	Do. 4ft. 0in. × 5ft. 6in. do.
,, 20th.	...	...	...	...	144	29,752	122	24,220	151°	31,661	Do. do. do.
Dec. 2nd.	71	14,904	112	32,056	107	35,523	...	...	...	...	Cylinders in do. do.
,, ,,	...	...	...	...	...	35,347	160	38,360	183	44,150	Cylinders out do. do.
,, 4th.	65	9,176	88	28,888	101	32,500	147	37,741	164	44,570	Do. do. do.
,, 10th.	...	11,249	...	...	77	23,018	132	33,428	161	37,707	Jets at top of Pit, Cylinders in.
Result Dec. 2nd & 4th	68°	12,040	100°	30,472	104°	34,456	153°5′	38,050	173°5′	44,360	Jets at bottom of Pit.
					Jets only.				Furnace & Jets.		
Ditto 10th	65°	11,249	...	...	77°	23,018	132°	33,428	161°	37,707	Jets at top of Pit.

Jets at Bottom of Pit.

TABLE XXIV.

General Result of the Experiments at Tyne Main Colliery.

Date.	Natural Ventilation.		Jets Alone.		Furnace Alone.		Furnace and Jets.		Remarks.
	Temperature.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	Temperatures.	Cubic feet per minute.	Temperature.	Cubic feet per minute.	
1853.									
January 14th.....	62°	34,955	62°	47,120	160°	91,495	198°	104,052	Jets at top of pit with Cylinders
,, 15th.....	62	36,873	62	49,576	262	102,503	272	106,830	
,, 28th.....	62°5	39,576	62°	47,417	...	...	...	...	Ditto without Cylinders
Average	62°	35,914	62°	48,348	211°	97,000	235°	105,441	Ditto with Cylinders
1852.	NORWOOD COLLIERY.								
August 10th	...	...	...	9,690	...	...	...	...	Jets 180 feet below surface.
,, 12th	98°	2,880	98°	6,000	98°	7,200	...	...	
	...	...	98	8,000	94	8,472	98°	9,000	
,, 13th	...	...	...	...	100	9,600	112	11,064	
Average	98°	2,880	98°	7,896	97°2′	8,424	105°	10,032	

The following Table is the mean result of the experiments made at Hetton Colliery :—

TABLE XXV.

Description of Power.	Mean Temperature of Upcast.	Cubic Feet of Air per minute.	Increase.	
			Temperature.	Cub. ft. of Air per minute.
Natural Ventilation	80°	121,478		
Engine Fires	89	132,053	9°	10,575
Ditto and Steam	94°5	139,512	5°5	7,459
Ditto ditto and Jets	101°5	166,133	7	26,621
Three Furnaces	170°5	206,477	69	40,344
Ditto Engine Fires and Steam	180°5	208,702	10	2,225
Ditto ditto and Jets	188	214,938	7°5	6,236

The following Table are the experiments made with One Furnace, December 11, 1852 :—

TABLE XXVI.

Description of Power.	Mean Temperature of Upcast.	Cubic feet of Air per minute.	Increase.	
			Temperature.	Cub. ft. of Air per minute.
Natural Ventilation	80°	117,908		
Engine Fires	81	121,464	1°	3,556
Ditto and Steam	82	129,569	1	8,105
Ditto ditto and Jets	88°7	146,010	6°7	16,441
One Furnace	95	166,826	6°3	20,816
One Furnace and Jets	124	194,075	29	27,249

The following Table is the mean result of the Killingworth Experiments :—

TABLE XXVII.

Description of Power.	Mean Temperature of Upcast.	Cubic feet of Air per minute.	Increase.	
			Temperature.	Cub. ft. of Air per minute.
Natural Ventilation	68°	12,040		
Steam alone	100	30,472	32°	18,432
Jets and Steam	104	34,456	4	3,984
Furnace	153°5	38,050	49°5	3,594
Furnace, Steam, and Jets	173°5	44,260	20	6,310

And the following Table is the mean result of the Experiments at Tyne Main :—

TABLE XXVIII.

Description of Power.	Mean Temperature of Upcast.	Cubic feet of Air per minute.	Increase.	
			Temperature.	Cub. ft. of Air per minute.
Natural Ventilation	62°	35,914		
Jets	62	48,348	...	12,434
Furnace	211	97,000	149°	48,652
Furnace and Jets	235	105,441	24	8,441

I shall now endeavour to elucidate the practical results exhibited by these experiments; and, first of all—

Natural Ventilation.

On an examination of the Tables and Diagrams, it will be seen that the amount of Natural Ventilation is very considerable, amounting, in the case of Hetton, to one-half of the most vigorous Ventilation produced; at Killingworth to nearly one-third; and at Tyne Main Colliery to fully one-third. The general temperature of the return air at Hetton is 69°, so that the mean temperature was 11° above that which the Natural Ventilation would produce in the shaft, leaving 104,775 cubic feet per minute due to a temperature of 69°. At Killingworth the mean temperature of the return air was 60°, showing 8° less than the temperature in the shaft, and leaving 10,623 cubic feet per minute for Natural Ventilation. Hetton arising from the upcast, not being cooled down sufficiently, and Killingworth from the heat given out by the steam pipes passing down the shaft. Tyne Main, the temperature in the shaft, and of the return air, was precisely the same; and, therefore, it was an accurate experiment of the amount of Natural Ventilation, on the day the experiment was made, amounting to nearly 36,000 cubic feet per minute.

I have, however, previously remarked, that Natural Ventilation is not to be depended upon—that the amount will vary as the temperature on the surface varies; the temperature in the mine not varying very materially in the different seasons of the year. It is necessary, therefore, that this should be attended to, in the practical Ventilation of the mine; and, if furnaces are used, that a more vigorous combustion should be urged in summer, to make up for the diminution of weight of the downcast air, by its increased temperature; and that if the Steam Jet, or mechanical

power, is applied, that they should be made to act more powerfully in summer than in winter.

The next description of power to be considered is, the

Boiler Fires, or Engine Fires.

The only place where this was experimented upon was at Hetton, where the boilers are placed at the bottom of the pit; at Killingworth and Tyne Main, the boilers were on the surface. The heat of the boiler fires, as measured by the temperature of the air in the shaft, acts precisely in the same manner as the furnace, by increasing the temperature, and so diminishing the weight of the column of the upcast shaft. I shall afterwards go into the question of the comparative consumption of coals between the engine fires, and the furnace, in producing the same temperature in the shaft; the question at present being as to the comparative efficiency of Ventilation of the column of air in the upcast shaft, heated by natural heat, and by the heat from the engine fires; or the additional amount of Ventilating power by the engine fires over the natural Ventilation. We have, in Table XXV., an addition of 10,575 cubic feet per minute, by the boiler Fires over Natural Ventilation; and, we have 121,478 cubic feet of air produced by a temperature of 80°, or 1,518 cubic feet for each degree with natural Ventilation; and with the engine fires, 132,053 with 89°, equal to 1,483 cubic feet for each 1°; the additional quantity of air, in this latter case, shewing an increased resistance. If we, however, take the latter case then 9° should have produced $9° \times 1{,}483 = 13{,}355$ cubic feet of air; whereas it only produced 10,575 cubic feet, or 1,175 cubic feet for each degree of temperature. The conclusion being, that the smoke from the engine fires adds to the density of the column in the upcast shaft, beyond that of a column of equal temperature heated by the natural heat of the mine.

We have next—

Engine Fires and Steam.

In the Hetton experiments, Table XXV., the increase by 5°·5 of temperature over the engine fires, was 7,459 cubic feet of air, or 1,356 cubic feet of air for 1°; which is greater than the quantity for each degree produced by the engine fires—though a still further increased resistance has to be overcome, by the increased velocity of the air. But, in this case, the steam is mixed up with the smoke from the engine fires, and it is difficult to determine what is due to each, although this experiment is sufficient to shew that the steam, by presenting a column of less specific gravity than the engine fires, produces an increased effect.

The experiments at Killingworth, Table XXVII., is, however, more decisive. In this case, the steam was applied, in addition to the natural heat, without any smoke, the boilers being at bank, and the steam conveyed to the bottom of the pit in pipes.

The natural heat of 68° gave 12,040 cubic feet per minute, or 177 cubic feet of air for 1°; and the steam, with a temperature of 100°, produced 30,472 cubic feet of air, or 304 cubic feet of air for each degree of temperature; though the increased quantity of air increased the resistance, the water gauge being, in the former case 1·50lbs. per square foot, and in the latter 3·30lbs.

This will also be seen on a reference to the experiment on December 4th, and to Diagrams V. and VIII., representing that experiment. It will be seen, also, that the resistance in the shaft is less with the steam than by Natural Ventilation, in the proportion of ·38 to 1·02. We thus see, what an important element of Ventilation steam is, applied at the bottom of the pit, and how likely we are to be deceived in the power of the Steam Jet, by not taking that element into consideration.

The value of steam as a Ventilating power, independently of being used as Jets, is shewn by a careful examination of these experiments. In the Killingworth experiments, Table XXVII., the steam heated 30·472 cubic feet of air 32°, or, 975·104 cubic feet of air 1°, we can thus ascertain the economy of employing steam in this manner. The quantity of steam used, could not, in this experiment, be correctly ascertained, but three boilers were at use in the manner described in Plate II., evaporating upwards of $2\frac{1}{2}$ cubic feet of water per minute, the steam being conveyed down the pit by a pipe 10 inches diameter, and the steam being kept blowing off into the shaft at 40lbs. pressure per square inch during the experiment; the quantity was sufficient to keep 29 Jets $\frac{2}{8}$th inch diameter, or an area of 1,423 inches, supplied with steam, as shewn in Plate II., Figs. 2 and 3, at 40lbs. per square inch.

We now come to the application, and performance of the Steam Jet, as a propulsive power; above that due to the rarefaction by the heat of the boiler fires, and of the steam in the upcast shaft.

Steam Jets.

I shall take the case of the application of the Jets, at Tyne Main Colliery first, as being applied at the top of the pit, and as acting solely

as a propulsive force, and not being affected by the heat of the engine fires, or of the steam in the shaft. In this case, the temperature of the air in the upcast shaft, was precisely the same, when the current of air was produced by the natural heat of the mine, and during the application of the Steam Jet; so that, on this account also, the Jets were not effected by the heat of the shaft. Fig. 8, Plate II., shews the mode of application at the top of the pit, 60 feet from the top of the shaft A., and level with the surface. Fig. 11 shews the Jets, 61 in number, $\frac{5}{16}$th inch diameter each, = 1,684 inches area. Cylinders being placed over the Jets, and the interstices between the cylinders, made quite air tight, so that the whole of the air and steam had to pass through the cylinders; and this was the case with the Natural Ventilation; and also when the Furnace was applied, the area through the cylinders being 40,258 square feet. The area of the shaft itself for 102 feet midway down, being 44·18 square feet, and above and below that, 50·257 square feet. So that we had 6 feet 40·258; 102 feet, 44·18; and 564 feet, 50·257 square feet area.

Table XXVIII. shows the Natural Ventilation, 35·914 cubic feet per minute, and the Jets, 48·348, leaving 12·434 cubic feet as the propulsive force of the Jets; the temperature of the air in the upcast shaft remaining the same during the experiment. No more conclusive experiment could be made than this, to determine the impulsive power of the Jets, when placed at the top of the pit. The water gauge shewing the force required to propel the air through the workings, was 2·4lbs. per square foot.

Table XXIII. shews the result at Killingworth, when the Jets were placed at the top of the pit. The Natural Ventilation was 11·249 cubic feet per minute. With the Jets, the quantity was 23·118, leaving 11·769 cubic feet for the Jets only, although the temperature was raised in the shaft from 65° to 77°, which ought to have given 2,280 cubic feet; the Jets in this case realising, therefore, only 9·489 cubic feet per minute. The water gauge in this case was 2·1lbs. per square foot, the area of the Jets being 1·423 inches.

Table XXV. gives the result at Hetton, and shews an increase of Ventilation by the Jets of 26·621 cubic feet per minute; but the increase of temperature being 7°, which would give $\frac{166·133}{161·5}$ 7° = 11·522, and which deducted from 26·621 leaves 15·099 cubic feet per minute, as the effective

impulsive power of the Jets. The water gauge in this case being about 5·13lbs. per square foot, and the area of the Jets 1·816 inches.

It must be observed, with reference to a comparison of these results, that the resistance of the air in the shaft, or through the Jets, in each case must be taken into consideration. In the experiment at Tyne Main, the velocity through the cylinders was 21·11 feet per second, and at Killingworth 19·96 feet per second. At Tyne Main, the area of Jets was 1·684 square inches, and at Killingworth 1·423 square inches. Taking all these into consideration, the correspondence between these experiments will be seen to be very near; and, therefore, we may take the Tyne Main experiment as a standard, for the propulsive power of Jets, placed at the top of the pit, viz.,—That steam of 40lbs. per square inch pressure, applied to Jets, of an aggregate area of 1·684 square inches, at the top of the upcast shaft, will produce an amount of Ventilation equal to 12·400 cubic feet of air per minute, the water gauge being 2·4lbs. per square foot, and the resistance up the shaft 2lb. per square foot; when the velocity through the cylinders is not greater than 21 feet per second. And we may add, that this result will require an evaporation of about 1·8 cubic feet of water per minute without waste, reckoning the velocity of the steam through the Jets at 1,080 feet per second; or, as per experiment, 1·83 cubic feet per minute, allowing for waste.

It has been stated, recently, by the advocates for the Steam Jet that the top of the pit is not the proper place to apply it; and that it should be applied at the bottom of the pit. No doubt, when placed at the bottom of the pit we have the advantage of the rarefaction of the boiler fires and steam. But the question before us at present is, does the Jets realise a greater impulsive force when placed at the bottom, or, when placed at the top of the pit?

The experiment, given in Table XXIII., at Killingworth, was made to determine this. From this Table it will be seen that the effect of the Jets over the Natural Ventilation was 22,416, viz: 34,416—12,040 cubic feet per minute; when the Jets were placed at the bottom of the pit. The increased temperature, however, was from 68° to 104°. Then $\frac{34,456}{104°} \times 36°$ = 11,926 cubic feet of air due to temperature; and, therefore, 34,456 — 12,040 + 11,926 = 10,490 cubic feet per minute due to the impulsive power of the Jets, *when placed at the bottom of the pit.* Then, December 10th, 23,018 — 11,249 = 11,769 cubic feet over Natural Ventilation; but the

temperature was increased from 65° to 77°, therefore $\frac{23,018}{77°} \times 12° = 3,576$; and 11,769 — 3,576 = 8,193 cubic feet per minute, the impulsive power of the Jet, *when placed at the top of the pit.* It must, however, be taken into account, that when the Jets were placed at the bottom of the pit, the openings around the Jets, or cylinders, were not closed, and that the area of the space, through which the air and steam had to pass, was about 30 feet; whereas, when the Jets were placed at the top of the pit, the air and steam had to pass through the cylinders of an area of little more than 19 square feet. Unless, therefore, the Jets could be applied, so that the resistance should be the same in both cases, the experiments would not be parallel. It is evident, however, that the bottom o the pit is the proper place to apply the Jets, as in that case the effect of the boiler fires and the steam will likewise be made available. There does not, however, appear to be any great difference in the mechanical effect, whether the Jets are placed at the top or bottom of the pit. If we take the case of Hetton, and Killingworth, at the bottom of the pit; and Tyne Main at the top, the following will be the comparative results:—

Colleries at which Experiments were made.	Velocity of air through cylinders or upcast shaft.	Pressure of steam per square inch.	Area of Steam Jets, in inches.	Cubic feet per minute of air.	Position of Jets.
	ft. per min.				
Hetton	1,061	40	1,816	15,099	Bottom of pit.
Killingworth ...	1,083	40	1,423	10,490	
Tyne Main.....	1,239	40	1,684	12,400	Top of pit.

We see, therefore, that there is no great difference, if any at all, in the *impulsive* force of the Jets, whether placed at the top, or bottom of the pit, and that the result of the experiment at Tyne Main Colliery, as given above, and the average of Hetton and Killingworth, may be taken as a standard of the impulsive force of the Jets; which is about 12,500 cubic feet per minute; area of Jets, 1·64 inches; steam at 40lbs. pressure per square inch; water guage about 4lbs. per square foot. Let us now see the power applied, and the effective performance. The evaporation of water at Tyne Main was, 1·82 cubic feet per minute, × 506 = 921 cubic feet of

steam at 40lbs. pressure per square inch. Area of shaft 40,258 square feet. Then $\frac{921}{40 \cdot 258} = 22 \cdot 77$ cubic feet of steam per minute for each foot area of shaft, at 40lbs. pressure per square inch. But the velocity of the air in the shaft is $\frac{49 \cdot 574}{40 \cdot 258} = 1231 \cdot 4$ feet per minute. Then as $22 \cdot 77 : 1231 \cdot 4 :: 40 :: \cdot 7396$lbs. per square inch on each foot of surface of the shaft, moving at the rate of 1231·4 feet per minute; or $\cdot 7396 \times 144 = 106 \cdot 5$lbs. per square foot, moving at the rate of 1231·4 per minute. Then $\frac{106 \cdot 5 \times 40 \cdot 258 \times 1231 \cdot 4}{33 \cdot 000} = 160$ horses' power, the power employed.

It is difficult to ascertain the precise effective performance; we have the water gauge equal to 2·4lbs. per square foot, but we have no measure of the resistence of the air in the shaft and through the cylinders; supposing, however, the dotted line, Plate IX., to represent these, being what would be the resistance if the furnace had been employed, it would be 2lbs. per square foot; and this would represent $\frac{4 \cdot 4 \times 40 \cdot 258 \times 1231 \cdot 4}{33 \cdot 000} = 6 \cdot 6$ horses' power, effective performance.

This very enormous loss of power seemed quite unaccountable, and I therefore instituted a set of experiments, with a view of endeavouring, if possible, to ascertain the cause. I have previously stated, that the Killingworth pit is divided into four compartments, by air tight timber brattices or partitions; one of those partitions formed the downcast, and the adjoining one the upcast, in the experiments at that colliery, shewn in Fig. 6, Plate II. It occurred to me, if I could ascertain the density, or degree of rarefaction of the air in the upcast, at all the different depths, as compared with that of the downcast, at the same depths, when the different modes of Ventilation was in operation, it might throw some light upon the matter. For this purpose, I had holes bored through the brattice or partition, between the downcast and upcast divisions of the shaft, at every 60 feet in depth from the surface to 600 feet; and then at every 3 feet from 600 feet to the bottom of the pit, into which I inserted the water gauge in the same manner as shewn in Fig 1, Plate II. (the door in this case representing the division between the two columns of air), and in this manner I obtained the comparative density of the two columns of the downcast and upcast shafts, at the various depths, when the different modes of Ventilation was in operation.

The following Table will show the result:—

TABLE XXIX.

Experiments on the density of the Air in the Upcast Shaft at Killingworth.

Depth of Shaft in feet.	Height of Water Gauge in inches.				
	Natural Ventilation.	Steam.	Jets, bottom of Pit.	Furnace.	Jets, top of Pit.
60	·025	·07	·05	·10	·10
120	·025	·10	·08	·115	·20
180	·075	·12	·12	·13	·275
240	·15	·20	·18	·20	·3
300	·25	·26	·25	·25	·35
360	·25	·28	·28	·35	·325
420	·25	·34	·30	·45	·3
480	·25	·45	·34	·57	·325
540	·25	·50	·375	·70	·35
600	·25	·60	·40	·78	·35
603	·25	·60	·42	·76	·35
606	·25	·62	·50	·78	·375
609	·25	·60	·45	·76	·375
612	·25	·60	·45	·80	·375
615	·25	·62	·45	·78	·375
618	·25	·62	·475	·77	·40
621	·25	·63	·45	·77	·4
624	·25	·63	·50	·70	·375
627	·25	·63	·50	·73	·375
630	·25	·65	·50	·70	·375
633	·225	·62	·55	·67	·35
636	·225	·64	·55	·68	·35
639	·20	·61	·60	·70	·35
642	·20	·63	·75	·70	·35
645	·20	·60	·70	·70	·325
648	·225	.60	·72	·75	·3
651	·225	·50	·70	·77	·35
654	·20	·58	·675	·76	·3
657	·20	·60	·675	·70	·325
660	·20	·60	·55	·74	·3
663	·20	·60	·50	·78	·3
666	·20	·60	·55	·80	·325

For the more clearly exhibiting the effect of the different moving powers, I have made two diagrams,—Plates X. and XI. It will be seen that below 600 feet the Water Gauge was taken every 3 feet;—this was done to shew more clearly the effect in the immediate vicinity of where the Jets and Furnace were applied, and the result will be found interesting.

It must, however, be observed, that these diagrams do not exhibit the actual degrees of rarefaction in the upcast shaft, but the comparative densities only, between the air in the downcast and the upcast shafts, at the various depths; the comparative areas of these diagrams, however, shew generally, the comparative ventilating powers of the different modes.

On a careful examination of these diagrams, it will be seen, that the Natural Ventilation presents a column of nearly uniform density throughout; near the top of the pit, the relative densities may be discarded. The steam is the same, especially in Plate XI., only shewing by its increased bulk the comparative elasticity of the column. The Furnace diagram shews an increased rarefaction in Plate XI., where the heated air enters the shaft, and for a considerable distance up the shaft in Plate X., when it gradually diminishes, as the depth from the surface becomes less. The steam Jets at the bottom of the pit exhibit a considerable increase of effect a little below, and immediately above the Jets; as much as the Furnace, but in a short distance it falls off, and the column gradually diminishes like the others; but it is to be remarked that though the quantity of steam issuing from the Jets was the same, the column No. 3, of the Steam Jet is much more dense, above 600 feet from the surface than the steam No. 2; shewing an increase of effect at and near the Jets, but a loss of effect in the upper part of the column. I had supposed, seeing that the effect both of the Furnace and the Jets, diminished towards the upper part of the column, that the application of the Jets at the top of the pit would have compensated for this;—and by exhausting the upper end of the column, we should have had a much greater combined effect; when we had the Jets at the top drawing out the air at one end of the column, and the rarifying power of the Furnace acting at the other end. And the result shewed that such an effect did to certain effect take place. It will be seen that in No. 5, with the Jets at the top of the pit, an increase of effect is obtained for at least half-way down the shaft, when the effect falls off, and diminishes much below that of the steam alone; but still nearly equal to the Jets placed at the bottom of the pit, except in their immediate vicinity, and within the operation of their impulsive power.

The diagram of the Jets shows pretty clearly the operation of the application of this power. Immediately below where the Jets are applied an increase of effect takes place, shewn by the increased rarefaction of the column, and produced, of course, by the propulsive force of the Jets acting on the column above, and creating a partial vacuum, or rarefaction, into

which the air from below rushes. [This was shewn, also, by some experiments at Tyne Main Colliery, by placing the Water Gauge with one end of the tube within the upcast, and the other end communicating with the outer air. The Water Gauge immediately below the Jets was ·24 to ·275 of an inch, and immediately above the Jets ·18 to ·2 of an inch. The Water Gauge at the Furnace doors ·2 Natural Ventilation, and ·325 to ·4 when the Jets were applied.] Immediately above the Jets an increased effect is likewise seen; but, this only takes place for a comparatively short distance above the Jets;—when such effect of, in fact, pushing up the column, appears to have the tendency to compress the column above, and thus to exhaust its power, and so produce a comparatively feeble effect.

When the Jets are placed at the top of the pit, it has also been deemed necessary to apply cylinders, and to close all the openings, or interstices, around the cylinders, to prevent eddies or any air from being drawn down the shaft, and so to repass through the cylinder to the exclusion of the air up the shaft. On examining the experiments made at Killingworth, Tables IX., X., and XI., it will be seen that no such action takes place, and that no sensible advantage is obtained by having the Jets placed within cylinders, whether the Jets are placed at the top or at the bottom of the pit; the shaft itself forming, indeed, the cylinder or chimney for the aggregate number of Jets, in place of one cylinder for each Jet. This will also be seen by an inspection of Tables XXIII. and XXIV.

Having thus shewn the particular action of the Jet, I shall now again revert to its mechanical effect in producing Ventilation. I have given a standard of its power when employed solely as a ventilating force; another mode of application, is that of its being employed as an auxilary to the Furnace, and, on an examination of the experiments, it will be seen that its power has been tested in this respect in a variety of cases, the results of which are given in the different tables, and are likewise shewn in the diagrams.

When employed alone, or solely as a ventilating power, with two or three boilers, the power is much below that of the Furnace, the Water Gauge not reaching beyond 4 lbs. per square foot, or, in extreme cases, 6 lbs. per inch; while with the Furnace, a Water Gauge of 12 lbs. per square foot has been reached. When the Jets are, therefore, to be applied as an

auxiliary to the Furnace, they will have to operate upon an increase of resisting medium; of, in fact, a Water Gauge of double the amount of that which they are capable of reaching when applied alone.

If, therefore, we find the Jets, applied alone, to produce a Water Gauge of 4 lbs. per square foot, or 12,000 cubic feet of air; and they are to be applied as an auxiliary to the Furnace, they have then to encounter a Water Gauge of 12lbs. per square foot; and then the same power, which, at a Water Gauge of 4 lbs. per square foot, produced 12,000 cubic feet of air, will, with 12 lbs. of Water Gauge, only produce 4,000 cubic feet of air,—and in this case the Jets have to encounter another disadvantage, in the increased velocity of the air on which they have to impinge.

Previously, however, to arriving at any conclusion, as to the effect of the Jets as an auxiliary to the Furnace; it will be necessary, first of all, to investigate the power of the Furnace as a ventilating force.

Furnace Ventilation.

The experiments with the Furnace, in its full vigour of action, as a ventilating power, were made at Hetton and Tyne Main; the experiments at Killingworth and Norwood, and also some of the experiments at Hetton, were made to compare the relative powers of the Jets, and of the Furnace, by an application of the latter, in a diminished power, or as nearly equal to the power of the Jets as possible.

Taking the experiments at Hetton, and referring to the general result, Tables XXV., and XXVII., we find the Furnaces producing an increased Ventilation of nearly 80,000 cubic feet of air per minute over that of the Natural Ventilation, and 40,344 cubic feet above that of the Natural, Engine Fires, Steam, and Jet, Ventilating Powers. And at Tyne Main Colliery 61,000 cubic feet above the Natural Ventilation, and 48,652 above that of the Jet Ventilation. It is unnecessary to do more than to refer to these experiments, (authenticated as some of them were by the presence of several of the Government Inspectors of Coal Mines, and also by a great many of the Viewers and Mining Engineers of the trade,) to shew; that when Furnace Ventilation is pushed to its maximum working effect, no application of Steam Jet yet applied, has reached within a considerable distance of the effective performance of its powers.

The highest water gauge reached by the Jets at Hetton Colliery was 5·13lbs per square foot, while the Furnaces produced 12 lbs. per square foot; more than double the power. At Tyne Main the water gauge by the Jets was 2·4lbs. per square foot, and that by the Furnace 7·2lbs., three times the power.

So far, therefore, as regards the application of the Steam Jet as a *substitution* of the Furnace, and considered with reference to their comparative powers, in producing the largest amount of Ventilation; and, consequently, as having a tendency in that respect to prevent accidents in Coal Mines, these experiments shew, in the most conclusive manner, that the Steam Jet, as hitherto employed, is far inferior to the Furnace in producing the largest amount of Ventilation in deep mines; and the experiments at Norwood Colliery shew, that with equal areas of fire grate, the Furnace is also superior to the Steam Jets in shallow mines.

I shall now consider the Steam Jet as an *auxiliary* to the Furnace, and it is in this capacity that it would appear, at first sight, to be available, if available at all. In the above remarks, I have confined myself to their comparative powers solely as mechanical forces in producing Ventilation. I shall afterwards go into their relative economy, and in the investigation of the application of the Steam Jet, as an auxiliary to the Furnace. I shall confine myself to the result deduced by these experiments, without indulging in any speculation, or probable increase of powers or improvements, to be hereafter realised, whether it may apply to the one power or to the other.

In arriving at a practical conclusion, as to the power of the Jets as an auxiluary to the Furnace, it will be necessary, first of all, to consider more particularly the power and efficiency of the Furnace, as deduced from these experiments.

In the case of the Hetton Colliery, the aggregate result of these experiments, Table XXV., shews the "Natural Ventilation" as equal to 121,478 cubic feet per minute, the temperature in the upcast shaft being 80°. And when the Furnace were applied, and the temperature raised to 170°5, the Ventilation was 206,477 cubic feet per minute;—or 40,344 cubic feet per minute above the effective performance of the Jet, although, in the latter case, the Jet had the advantage of the rarefaction of the heat from the boiler fires, and from the steam issuing from the Jets. At Tyne

Main, Table XXVIII., the effect was 97,000, or an increase above the Jets of 48,652 cubic feet per minute.

The experiments represented in diagrams, Plate IV. and VI., and Plates VII. and IX., also shew the comparative power of the Furnace and Steam Jets, in the most conclusive manner.

In the Hetton experiments, Plate VII., the effective performance of the Furnace is 225,176 cubic feet of air per minute, or $11{\cdot}70 + 6{,}518 =$ 18,218lbs. pressure per square foot area of the shaft, at a velocity of $\frac{225{,}176}{153} =$ 1,475 feet the minute; and consequently $\frac{18{,}218 \times 1{,}475 \times 153}{33{,}000} = 124{\cdot}6$ horses' power.

The effective performance of the Jets was 164,000 cubic feet of air per minute, or $5{\cdot}13 + 4{\cdot}7 = 9{\cdot}83$lbs. pressure per square foot area of shaft, at a velocity of $\frac{164{,}000}{153} = 1{,}072$ feet per minute; and consequently $\frac{9{\cdot}83 \times 1072 \times 153}{33{,}000}$ $= 48{\cdot}86$ horses' power. But to obtain the performance of the Jets as a mechanical or propulsive force, we must deduct the effect of the engine fires and steam, which was $3{\cdot}6 + 2{,}675 = 6{\cdot}275$lbs. per square foot of shaft. Then $\frac{139{,}847}{153} = 914{\cdot}1$ feet per minute, and $\frac{6{,}275 \times 914{\cdot}1 \times 153}{33{,}003} = 26$ 6 horses' power deducted from 48·86 leaves 22·26 horses' power as the effective performance of the Jet, though the increased temperature above that of the engine fires ought also to be deducted. This gives the relative performances as 124·6 : 26·6 for the Furnace and Jets. The Water Gauge being 5·13lbs. per square foot. And this result, as will hereafter be seen, is that of three Furnaces consuming under 20lbs. of coal per minute, the Jets requiring 25lbs. per minute; and the latter with an evaporation of 1·55 cubic feet of water per minute, applied in 37 Jets, $\frac{2}{8}$ths of an inch diameter, or an area of 1·816 inches, with steam at 40lbs. per square inch, applied at the bottom of the pit.

The experiment at Tyne Main, represented in Plate IX., will shew that the Furnace Ventilation was $7{\cdot}2 + 8{\cdot}477 = 15{,}677$lbs. pressure per square foot area of shaft, at a velocity of $\frac{102{\cdot}503}{50{\cdot}257} = 2039{\cdot}8$ feet per minute— and $\frac{15{,}677 \times 2039{\cdot}1 \times 50{,}257}{33{,}000} = 48{\cdot}7$ horse power.

The Steam Jet performance was $2{\cdot}4 + 2 = 4{\cdot}4$lbs. pressure per square foot area of shaft, at a velocity of $\frac{49{\cdot}574}{50{\cdot}257} = 986{\cdot}4$ feet per minute— and $\frac{4{\cdot}4 \times 986{\cdot}4 \times 50{,}257}{33{,}000} = 6{\cdot}6$ horses' power.

Consequently the relative effective performance at Tyne Main Colliery is as 48·7 : 6·6 for the Furnace and Jets; the Furnace consuming about 16lbs. of coal per minute, and the Jets 21lbs., with 61 Jets $\frac{3}{16}$ths of an inch diameter, or 1,684 inches area. Steam 40lbs. per square inch, applied at the top of the pit, and with an evaporation of 1·82 cubic foot of water per minute.

On comparing these results, it will be seen that the experiment at Tyne Main Colliery shews a greater comparative result, as regards the Furnace, than Hetton. It must, however, be taken into consideration that the Furnaces at Tyne Main were urged with more vigour than Hetton, the temperature of the air in the upcast with the former being 262°, and in the latter 211°; though the evaporation of water at Hetton, with the Jets, was 1·55, while at Tyne Main it was 1·82 cubic feet per minute.

These experiments were made to test the absolute comparative power of the two systems. Those at Killingworth, and with one Furnace at Hetton and at Norwood, were made to test their comparative *economy*, when the powers were as nearly equal as possible, and which I shall go into hereafter.

The object in this stage of the inquiry, being to ascertain if the Steam Jet is capable of a greater performance than the Furnace; and if it can be applied as a substitution of the Furnace, so as to produce a more powerful ventilating force, and so render the mines more safe.

The result at Hetton would shew, that in order to produce an equal effect with the Jets as with the Furnaces, the power of the Jets would require to be increased in the ratio of 124·6 : 26·6 exclusive of the effect of the heat of the Engine Fires and Steam; and at Tyne Main in the ratio of 48·7 : 6·6, supposing no loss of power takes place with the Jets when the velocity of the air which they have to propel is increased. The velocity of the air propelled by the Jets at Hetton was 914 feet per minute, while it was 1,072 feet per minute when the Furnace was applied; and at Tyne Main, with the Jets 986, and with the Furnace 2,039 feet per minute.

Sufficient, therefore, appears to be shewn by these experiments, that as a *substitution* for the Furnace there would require to be a very great increase in the consumption of coals in the application of the Jets, to reach the same ventilating power as the Furnace; that as a *substitution*

its application is inadmissable; and that the only mode in which the Jet can be applied, if applied at all, is as an *auxiliary* to the Furnace, and in this capacity we shall now proceed to investigate its efficiency.

Furnace and Steam Jets.

Diagram, Plate VII., shews the increase of Ventilation of the Steam Jets in addition to the Furnaces, and which is 7,249 cubic feet per minute; but, it will be observed, that the temperature was increased from 226° to 229° or 3°. This must, therefore, be taken into account. The Furnace and Engine Fires gave 229,918 cubic feet per minute, the temperature being 226°. Suppose the same effect to take place by an increase of 3° beyond 226°, we have $\frac{229,918 \times 3^{\circ}}{226^{\circ}} = 3,052$, which, deducted from 7,249, leaves 4,197 cubic feet per minute, due to the propulsive power of the Jets, the velocity of the air on which they impinged being 2,094 feet per minute.

Again, at Killingworth, diagram, Plate VIII., the increase was 6,859 cubic feet per minute, the increase of temperature being 17°. Then $\frac{37,741 \times 17^{\circ}}{147^{\circ}} = 4,364$, which deducted from 6,859, leaves 2,495 cubic feet per minute, due to the impulsive power of the Jets, the velocity of the air on which the Jets acted being 1,815 feet per minute.

The Jets in both of these cases were applied at the bottom of the pit. We have no means, as before stated, of ascertaining the precise resistance of the air in the shaft when the Jets are applied; but, taking the Water Gauge, as a measure of the efficient practical effect of the Jets in the different modes of application; we have, as the impulsive powers of the Jets,—

	Jets Alone.		Furnace and Jets.	
	Cubic feet of Air per min.	Water Gauge in lbs. per square foot.	Cubic feet of Air per min.	Water Gauge in lbs. per square foot.
Hetton Colliery	15,099	5·13	4,197	12·38
Killingworth Colliery	9,489	2·1	2,495	7·5

Shewing a diminution of effect, when the velocity of the air on which the Jets act is increased; and certainly a very small effect in addi-

tion to the Furnace; considering, that a quantity of steam issuing out of an aggregate area of 1·8133 inches at 40lbs. pressure per square inch, and an evaporation of 1·55 cubic feet of water per minute, was employed at Hetton; and steam at 40lbs. pressure per square inch, with an area of Jets of 1·423 inches, was employed at Killingworth.

There are also several other allowances to make if these experiments were strictly construed, which would diminish the comparative result of the Jets; but, as before stated, my object being to shew the result in a practical manner, I have abstained from going into the subject, in a close, theoretical, or abstruse character; the experiments, however, are furnished in such a manner, that this can be gone into by any one, and on a future occasion, and the details will, of itself, be found to be sufficiently interesting and useful.

I shall now give the result of the experiments made to ascertain the comparative *economy* of the two systems, as regards the consumption of coals, or power employed, and the corresponding effective performance produced.

For this purpose, the entire Furnace Ventilation power of Hetton Colliery was made the subject of experiment for 24 hours consecutively,—the Jet Ventilation at Hetton was made the subject of experiment for 12 consecutive hours;—and, that the comparison between the Furnace and Jets should be made the subject of experiment, under as precisely the same circumstances, or as nearly equal power as possible, two of the Hetton Furnaces were extinguished, and an experiment for 12 hours was made on the ventilating power of one Furnace to compare with the Jets.

Similar experiments were made at Tyne Main Colliery, to ascertain the relative economical performances of the Furnace and Steam Jets.

The details of the Hetton experiments are given in Tables V., VI., VII., and VIII.; and the experiments at Tyne Main, in Tables XII. and XVIII.; and the following Table shews the general results.

TABLE XXX.

Result of Experiments at Hetton and Tyne Main Collieries on the Consumption of Coal.

Time.	Description of Experiments.	Temperature.						Cubic feet of air passing down the Downcast Shafts per minute.	Water Gauge.	Consumption of Coals.	
		At Bank.	In Return Air.	Bottom of Downcast.	Upcast faths. 10.	Upcast faths. 65.				lbs. per minute.	Cubic feet of air for each lb. of coal.
1852.											
Nov. 26th & 27th	3 Furnaces	44°	68°	45°	...	130°	Hetton Colliery.	208,466	Inch. 1·20	18·86	11·066
1853.											
January 3rd	37 Jets $\frac{1}{4}$ inch. dia. each	45	68	46	86°	90		159,913	·80	25·28	6·400
January 8th	1 Furnace, 9 Feet	44	68	45	94	98 5		164,750	1·00	10·11	16·320
January 20th.....	2 Furnaces	49·75	63	51	161 ·75	145 ·5	Tyne Main Colliery.	101,876	·925	16·76	6·080
January 28th.....	61 Jets, $\frac{3}{16}$ Inch diameter	35 5	62 5	40	30 fms. 63 ·75			47,467	·38	21·32	2·223

The result of the experiments at Hetton is, that with one Furnace, and when the Furnace Ventilation of the Colliery was reduced so as to be as nearly as possible equal to that of the Jets, the consumption of coals with the Furnace was 10·11lbs. per minute—the consumption with the Jets 25·28 lbs. :—the quantity of air produced by each lb. of coal being, with the Furnace 16,320 cubic feet per minute, and with the Jets only 6,400 cubic feet per minute. So far, therefore, as regards their *comparative economy*, when the powers are nearly alike, the economy is in favour of the Furnace as 2·55 : 1 ; when the Jets are placed at the bottom of the pit, and having the aid of the heat from the boiler fires, and the steam, as assistant Ventilating Powers.

As a *substitute* for the Furnace, the Steam Jets are, therefore, decidedly deficient, when the powers are equal, and when the only motive for substitution, is economy ; and this, it will be seen, holds good, or is increased in favour of the Furnace, when working at a higher Water Gauge, and within the limits in which *substitution* is practicable, and this we shall now consider.

The experiment on the 26th and 27th November, Table XXX., shews the Furnace power, of the every day working of the Hetton Colliery, three Furnaces *B B* and *C*, Figs. IV. and V., Plate I., unaided by the engine fires *E* ;—the amount of this Ventilation is 208·466 cubic feet per minute. Supposing the Steam Jet Ventilation increased by additional Boilers and Jets to this extent, and that the consumption of coals is not comparatively greater. Comparing, then, the experiments with the single, and with three Furnaces, we find the increase of the consumption of coal for each cubic foot of air as 16,320 : 11,066, the increase by the Jets will be, from the preceding investigations, in a greater ratio ; suppose, however, it is the same, then we have as 16,320 : 11,066 : : 6,400 : 4,340 cubic feet of air for each lb. of coal by the Jets. When the Jet Ventilation is, therefore, carried to the standard of the three Furnaces, the quantity of air for each lb. of coal by the Furnaces being 11,066; the relative consumption of coals, by the substitution of Steam Jet for the Furnace Ventilation at Hetton Colliery, will be as 11,066 : 4,340, or nearly three times the quantity with the Steam Jets, as with the Furnace, at the every day working of the Furnace power of Hetton Colliery.

At Tyne Main Colliery the result is nearly the same, as will be seen by Table XXX., the relative quantity of air per each lb. of Coal, being as 6·080 : 2·223, and this is the result, the Water Gauge of the Jets being ·38, and the Furnace ·925 inches.

It will be seen from the experiments at Hetton (Table XXX.), that the impulsive force of the Jets, is about the same as that which resulted from the previous experiments. The quantity of air by the single Furnace was 164·750 cubic feet per minute, with a mean temperature of 98°5 = 1,672 cubic feet of air per minute for each degree of heat; the mean temperature of the heat from the engine fires and steam was 90°; therefore 90° × 1672 = 150·480, deducted from 159·913, leaves 8·573 cubic feet per minute; due to the impulsive force of the Jets, the mean of twelve hours' experiment; with a Water Gauge of 4·8 lbs. per square foot—the Jets at the bottom of the pit.

And at Tyne 47,407 cubic feet per minute (Table XXX.) less 35·914 (the Natural Ventilation as per Table XXVIII.) = 11,493 cubic feet per minute, with a Water Gauge of 2·28lbs. per square foot, the Jets being at the top of the pit.

The practical conclusions, resulting from these experiments, may be Tabulated as follows :—

STEAM JETS AS A SUBSTITUTION OF THE FURNACE.

HETTON COLLIERY—JETS AT BOTTOM OF PIT.

	Due to temperature of upcast shaft.	Impulsive force of Jets.	Total.	Consumption of Coal.
	Cubic feet of air per minute.	Cubic feet of air per minute.	Cubic feet of air per minute.	lbs. per minute.
FURNACE	208·466	—	208·466	18·86
	164·750	—	164·750	10·11
JETS..	151·340	8573	159·913	25·28

TYNE MAIN COLLIERY—JETS AT TOP OF PIT.

	Due to temperature of upcast shaft.	Impulsive power of Jets.	Total.	Consumption of Coal.
	Cubic feet of air per minute.	Cubic feet of air per minute.	Cubic feet of air per minute.	lbs. per minute.
FURNACE...	101·876	—	101·876	16·76
JETS.....	35·914	11·493	47·407	21·32

STEAM JETS AS AN AUXILIARY TO THE FURNACE.

HETTON COLLIERY—JETS AT BOTTOM OF PIT.

	Due to temperature of upcast shaft.	Impulsive power of Jets.	Total.	Consumption of Coal.
	Cubic feet of air per minute.	Cubic feet of air per minute.	Cubic feet of air per minute.	lbs. per minute.
FURNACE ...	208·466	—	208·466	18·86
JETS	208·466	4917	213·383	47·97

In these investigations, I have not taken into account the quantity of air required to work the engine fires, when the Jets are placed at the bottom of the pit; a quantity more than the impulsive power of the Jets, as it may be said this air might be obtained from the return air after passing through the workings. I have great doubts that this can be beneficially accomplished, but as I could not ascertain this by experiment, I have not made any allowance for the increased loss of power in the Jets by such air passing up the shaft, which I ought otherwise to have done.

In conclusion, the practical result of all these experiments is, that within the limits or range of Furnace Ventilation, the Steam Jet acting as a *substitute*, is attended with an increase in the expenditure of fuel of, nearly 3 : 1, without any corresponding advantage either in the steadiness security, or efficiency of Ventilation ; on the contrary, from its simplicity of construction, the steadiness of its action, its less liability to derangement, its economy, and its efficiency in cases of emergency, the Furnace is a more secure, more safe, and more eligible mode of Ventilation than the Steam Jet.

And, with respect to the Steam Jet as an *auxiliary* to the Furnace, the conclusion is, that the increase of effect of the Jets over the Furnace is quite inconsiderable,—that such increase is extremely unsteady, in some cases nothing at all, when the Furnace is urged to its maximum effect ; and, in the ordinary working state of the Furnace (supposing the Furnace kept within its limit, so as to have adequate spare power in cases of emergency), amounting to only about 2 or $2\frac{1}{2}$ per cent. That such increase is, however, attended with a loss of power, or increase in the consumption of Coal, as compared with the Furnace, of nearly 3 : 1. And, taking into account the uncertainty of its action, and that the increase of 2 to $2\frac{1}{2}$ per cent. is only obtained when the Furnace is about 10 per cent. within its maximum power ; (see Experiment, Plate VII., and Experiment, Table

V.,) and seeing, likewise, that when the Furnace is urged to its maximum power, in cases of emergency, an increase of 10 per cent. can be immediately obtained by the Furnace; (see Experiment, page 68,) it is quite clear that the Steam Jet is equally ineligible and inefficient, as an *auxiliary*, as when applied as a *substitute* for the Furnace in the Ventilation of CoalMines.

And, setting aside all considerations of loss of power, or of economy, and looking only to the two ventilating powers, with reference to their comparative efficiency of producing increased Ventilation, and so adding to the security and safety of the Mine; (for I agree with the Committee of the Commons of 1852, "That a generally increased Ventilation is the truest security against explosions,") it is quite clear, that it would neither be advisable nor safe to depend upon any increased quantity of air as a security from explosions, which might be obtained by the Steam Jet above that which can be obtained from the Furnace; and, that the only safe and secure dependence, so far as regards vigorous Ventilation, as a security against explosions; is, upon a well-constructed Furnace, or Furnaces,—proper adaptation and arrangement of shaft power,—capacious air passages,—and upon a well-regulated distribution of the air currents; and, not upon the complicated and uncertain action of the Steam Jet.

And, lastly, I must beg permission to point out the deep obligations which the Institute and Mining Interests generally are under to the Hetton, the Marley Hill, and the Tyne Main Coal Companies; for their liberality, in placing their Pits at my disposal, and for the expense and inconvenience which they have been put to, in the prosecution of these experiments; and I have also to express the obligations I am personally under to them, and to Messrs. Johnson, Greenwell, Liddell, and Wales, the Viewers at these Collieries; and to the other gentlemen, from whom I have reeceived aid and assistance in this arduous undertaking.

NICHOLAS WOOD.

APPENDIX No. 1.

Synopsis of the Ventilation of Hetton Colliery, with the respective Distances which each Current of Air travels, and the quantity of Air in each Split.—October 28th, 1853.

MAIN CURRENTS.

MINOR EAST DOWNCAST PIT; HUTTON SEAM.

		Cubic feet ℔ minute.	Area of air courses.
1.	Through the West Stables	2,000	36
2.	First West Incline	11,500	40
3.	Stone Drift Incline	6,200	49
4.	Middle North Way	5,800	49
5.	North-East x Cut	7,150	50
6.	First East Way, Engine Plane	6,500	50
7.	South-East x Cut	6,200	50
1.′	From the Eppleton West Drifts, through Lyons Waste	,,	
2.′	From Ditto ditto	,,	
		45,350	

MINOR WEST DOWNCAST PIT; HUTTON SEAM.

		Cubic feet ℔ minute.	Area of air courses.
1.	Middle South Way	7,500	30
2.	Low South Way	8,300	30
3.	South x Cut Way	7,600	40
4.	East Engine Plane	8,400	40
5.	Third North Way	7,700	30
6.	Through Elemore Isabella Pit; North Way and through the Minor Pit Waste	10,300	40
		49,800	

APPENDIX No. I.—Continued.

EPPLETON JANE DOWNCAST PIT; HUTTON SEAM.

	Cubic feet ℔ minute.	Area of air courses.
1. High West Drift Way	5,600	49
2. Fourth North-West Drift Way	6,000	30
3. North beyond the Engine (West)	3,200	25
4. Ditto ditto (East)	3,500	25
5. Second South Way, down the Engine Plane	5,500	42
6. Second North Way ditto	5,400	36
7. Third South Way ditto	5,100	36
8. Fourth North Way ditto	5,400	40
9. Fourth South Way ditto	5,000	40
10. Fifth North Way ditto	5,700	40
11. East Drift Way ditto	5,300	40
Eppleton	55,700	

MINOR EAST DOWNCAST PIT; LOW MAIN SEAM.

	Cubic feet ℔ minute.	Area of air courses.
1. First North East Way	7,500	36
2. Second North East Way	6,400	36
3. South East Way	5,100	25
4. First West Way, south side	5,000	25
5. First West Way, north side	5,200	25
Total	29,200	

MINOR WEST DOWNCAST PIT; MAIN COAL SEAM.

	Cubic feet ℔ minute.	Area of air courses.
1. South District	7,000	50
2. West District	5,500	30
3. North District	7,450	50
4. From the Eppleton Shaft, West; and North to Blossom Shaft...	10,000	30
Total	29,950	

TOTAL MAIN CURRENTS.

	Cubic feet ℔ minute.
East Minor Pit	45·350
West Minor Pit	49·800
Eppleton Pit	55·700
Low Main Seam	29·200
Main Coal Seam	29·950
Total	210·000

The area of the air courses, as above given, are those of the splits, or the "Ingoing" and "Outcoming" single currents: when the split, or single currents are united, the area of the air courses are proportionably increased.

APPENDIX No. 1.—CONTINUED.

Statement of the Distances travelled by the various Currents of Air in the Minor East Pit, Hutton Seam at Hetton Colliery, through the Workings, and returns to the Blossom Pit Upcast.—Oct. 28, 1852.

Splits	"In-going," or "Fresh Air Currents."								See account of Eppleton.	
	.....	1.	2.	3.	4.	5.	6.	7.	1′.	2′.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1, 2, 3, 4, 5, 6, & 7	88	88	88	88	88	88	88	88	...	...
1	44	44	...	...	...	...	...	...	...	...
2, 3, 4, 5, 6, and 7	407	...	407	407	407	407	407	407	...	...
2	594	...	594	...	...	...	...	...	...	...
3, 4, 5, 6, and 7	132	...	...	132	132	132	132	132	...	...
3, and 4	440	...	...	440	440	...	...	...	...	...
3	880	...	...	880	...	...	...	...	...	...
4	880	...	...	...	880	...	...	...	...	...
5, 6, and 7	638	...	...	...	...	638	638	638	..	...
5	110	...	...	...	...	110	...	...	...	...
6, and 7	462	...	...	...	...	...	462	462	...	...
6	286	...	...	...	...	...	286	...	...	...
7	462	...	...	...	...	...	...	462	...	...
		132	1089	1947	1947	1375	2013	2189	...	...

Splits	"Outcoming," or "Return Air Currents."									
	.....	1.	2.	3.	4.	5.	6.	7.	1′.	2′.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1	44	44	...	...	...	...	...	...	...	...
1, 2, 3, 4, 5, 6, 7, and 1′ and 2′	143	143	143	143	143	143	143	143	143	143
2	1078	...	1078	...	...	...	...	...	...	...
3	1144	...	...	1144	...	...	...	...	...	...
4	1452	...	...	...	1452	...	...	...	...	...
3 and 4	352	...	...	352	352	...	...	...	...	...
3, 4, 5, 6, 7, and 1′ and 2′	913	...	...	913	913	913	913	913	913	913
5	484	...	...	...	...	484	...	...	...	...
6	1100	...	...	...	...	...	1100	...	...	...
7	957	...	...	...	...	...	...	957	...	...
6 and 7	704	...	..	...	...	...	704	704	...	...
1′ and 2′	880	...	...	...	...	...	...	...	880	880
		187	1221	2552	2860	1540	2860	2717	1936*	1936*
Brought down		132	1089	1947	1947	1375	2013	2189	2684	2508
Total distance		319	2310	4499	4807	2915	4873	4906	4620	4444

* See Eppleton Account.

APPENDIX No. 1.—Continued.

Statement of the Distances travelled by the various Currents of Air in the Minor West Pit, Hutton Seam, at Hetton Colliery, through the Workings, and returns to the Blossom Pit Upcast.—Oct. 28, 1852.

	"In-going," or "Fresh-Air Currents."						
Splits	.....	1.	2.	3.	4.	5.	6.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1, 2, 3, 4, and 5	737	737	737	737	737	737	From Elemore.
1 and 2	462	462	462	...	...	...	
1	671	671	...	...	...	...	
2	792	...	792	...	...	...	
3, 4, and 5	308	...	...	308	308	308	
3	330	...	...	330	...	...	
4 and 5	737	...	...	...	737	737	
4	286	...	...	...	286	...	
5	341	...	...	...	...	341	
		1870	1991	1375	2068	2123	2816

	"Out-coming," or "Return Air Currents."						
Splits	.....	1.	2.	3.	4.	5.	6.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds
1	1199	1199	...	...	...	...	From Elemore through Minor Waste.
2	1276	...	1276	...	...	...	
3	638	...	...	638	...	...	
4	286	...	...	...	286	...	
5	330	...	...	...	...	330	
4 and 5	968	...	...	...	968	968	
1, 2, 3, 4, and 5	1562	1562	1562	1562	1562	1562	
		2761	2838	2200	2816	2860	4664
Brought Down		1870	1991	1375	2068	2123	2816
Total Distances		4631	4829	3575	4884	4983	7480

APPENDIX No. 1.—Continued.

Statement of the Distances travelled by the various Currents of Air in the Jane Pit; Hetton Seam, at Eppleton Colliery, through the Workings and Returns to the Blossom Pit Upcast at Lyons, October 28, 1852.

Splits	"Ingoing," or "Fresh Air Currents."											
	.....	1′.	2′.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1′, 2′, 3, 4, 5, 6, 8, 9, 10, and 11	110	110	110	110	110	110	110	110	110	110	110	110
1′ and 2′	1122	1122	1122	...	...	...	...	...	...	...	...	..
1′	594	594	...	...	...	...	...	...	...	...	...	...
2′	572	...	572	...	...	...	...	...	...	...	...	...
3, 4, 5, 6, 7, 8, 9, 10, and 11	209	...	...	209	209	209	209	209	209	209	209	209
3 and 4	396	...	...	396	396	...	...	...	...	...	...	...
3	396	..	...	396	...	...	...	...	...	...	...	...
4	330	...	...	...	330	...	...	...	...	...	...	...
5, 6, 7, 8 9, 10, and 11	880	...	...	...	...	880	880	880	880	880	880	880
5	935	...	...	...	...	935	...	...	...	...	...	...
6, 7 8, 9, 10, and 11	15	...	...	...	...	...	15	15	15	15	15	15
6	1353	...	...	...	...	...	1353	...	...	..	...	...
7, 8, 9, 10, 11	297	...	...	...	...	...	...	297	297	297	297	297
7	825	...	...	...	...	...	...	825	...	...	...	...
8, 9, 10, and 11	143	...	...	..	...	...	...	...	143	143	143	143
8	792	...	...	...	...	...	...	...	792	...	...	...
9, 10, and 11	348	...	...	...	...	...	...	...	...	348	348	348
9	1441	...	...	...	...	...	...	...	...	1441	...	...
10	561	...	...	...	...	...	...	...	...	...	561	...
11	1628	...	...	...	...	..	...	...	...	...	...	1628
		1826	1804	1111	1045	2134	2567	2336	2446	3443	2563	3630

Splits	"Outcoming," or "Return Air" Currents.										
	.....	1′.	2′.	3.	4.	5.	6.	7.	8.	9.	10.	11.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1′	748	748	...	...	...	...	...	...	...	...	...	...
2′	594	...	594	...	...	...	...	...	...	...	...	...
1′ and 2′	110	110	110	...	..	..	...	...	...	...	...	...
3	847	...	...	847	...	...	...	...	...	...	...	...
3 and 4	2178	...	..	2178	2178	...	...	...	...	...	...	..
5	1287	...	...	...	...	1287	...	...	...	...	...	...
6	1496	...	...	...	...	...	1496	...	...	...	...	...
8	1903	...	...	...	...	...	...	...	1903	...	...	...
10	891	...	...	...	...	...	...	...	...	...	891	...
8 and 10	242	...	...	...	...	...	...	...	242	...	242	...
6, 8, and 10	352	...	...	...	...	...	352	..	352	...	352	...
7	726	...	...	...	...	...	...	726	...	...	...	...
9	1419	...	...	...	...	...	...	...	...	1419	...	...
11	737	...	..	...	...	...	...	...	...	...	...	737
9 and 11	660	...	...	...	...	...	...	...	...	660	...	660
7, 9, and 11	352	..	...	...	...	...	...	352	...	352	...	352
3, 4, 5, 6, 7, 8, 9, 10, and 11	3509	...	...	3509	3509	3509	3509	3509	3509	3509	3509	3509
		858	704	6534	5687	4796	5357	4587	6016	5940	4994	5258
Brought down		1826	1804	1111	1045	2134	2567	2336	2446	3443	2563	3630
Total distances		2684	2508	7645	6732	6930	7924	6923	8462	9383	7557	8888

APPENDIX No. 1.—Continued.

Statement of the Distances travelled by the various Currents of Air in the Minor East Pit, Low Main Seam, at Hetton Colliery, through the Workings, and returns to the Blossom Pit Upcast.

Splits	"In-going," or "Fresh Air Currents."					
	.....	1.	2.	3.	4.	5.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1, 2, and 3	120	120	120	120	...	...
1	940	940	...	...	...	...
2 and 3	290	...	290	290	...	...
2	230	...	230	...	...	...
3	200	...	...	200	...	...
4 and 5	725	...	...	...	725	725
4	200	...	...	..	200	...
5	315	...	..	...	...	315
See below for Totals.		1060	640	610	925	1040

Splits	"Out-coming," or "Return Air Currents."					
	.....	1.	2.	3.	4.	5.
	Yds.	Yds.	Yds.	Yds.	Yds.	Yds.
1	220	220	...	...	...	...
2	220	...	220	...	...	...
1 and 2	185	185	185	...	...	...
3	670	..	...	670	...	...
1, 2, and 3	100	100	100	100	...	...
4	460	...	...	...	460	...
5	360	...	...	...	..	360
4 and 5	1595	...	...	..	1595	1595
		505	505	770	2055	1955
Brought down	.....	1060	640	610	925	1040
Total Distances	.....	1565	1145	1380	2980	2995

APPENDIX No. I.—Continued.

Statement of the Distances travelled by the various Currents of Air in the Main Coal Seam, at Hetton Colliery, through the Workings, and returns to the Blossom Pit Upcast Shaft.

Splits.....	"In-going," or "Fresh Air Currents."				
	.....	1.	2.	3.	4.
	Yds.	Yds.	Yds.	Yds.	Yds.
1	1165	1165	...	...	...
2	560	...	560	...	...
3	1080	...	...	1080	...
4	2360	...	...	...	2360
See below for Totals.....	1165		560	1080	2360

Splits.....	"Out-coming," or "Return Air-Currents."				
	.....	1.	2.	3.	4.
	Yds.	Yds.	Yds.	Yds.	Yds.
1	7010	7010	...	...	...
2	1220	...	1220	...	...
3	1620	...	...	1620	...
4	6460	...	...	...	6460
		7010	1220	1620	6460
Brought down.....		1165	560	1080	2360
Total distances		8175	1780	2700	8820

PLATE I.

Fig. 1.

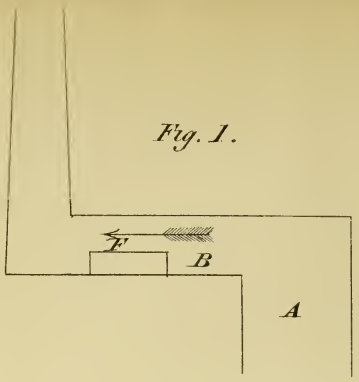


Fig. 3.

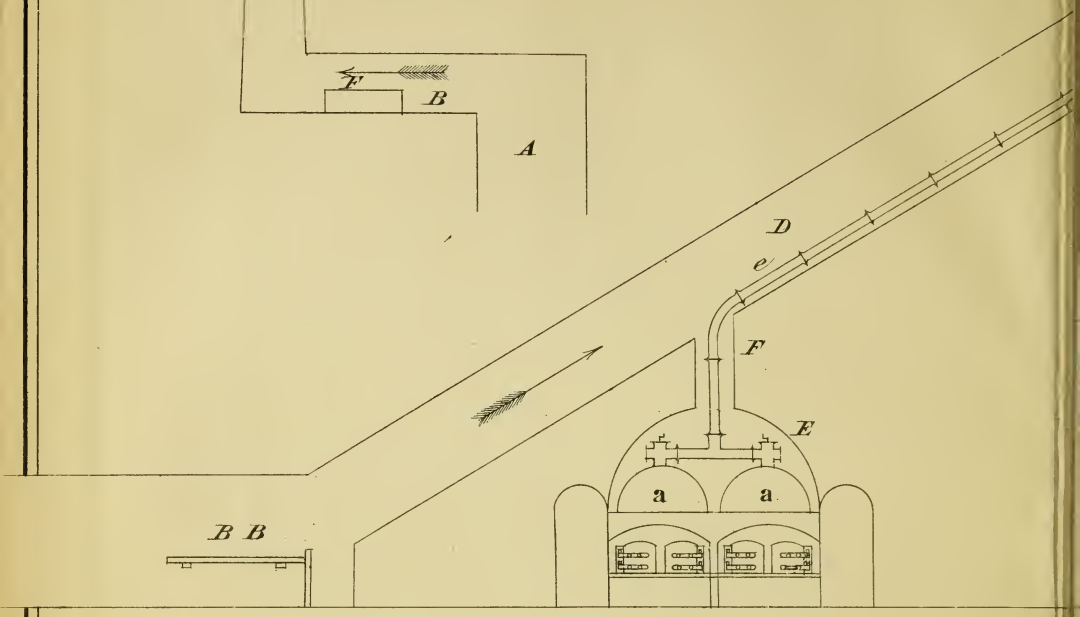


Fig. 4.

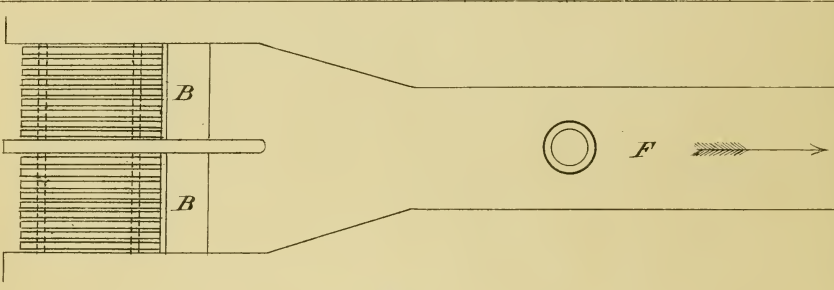
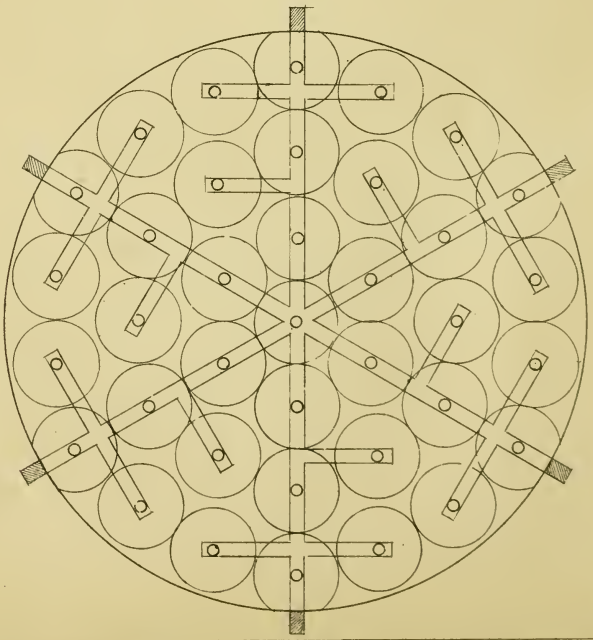


Fig. 8.



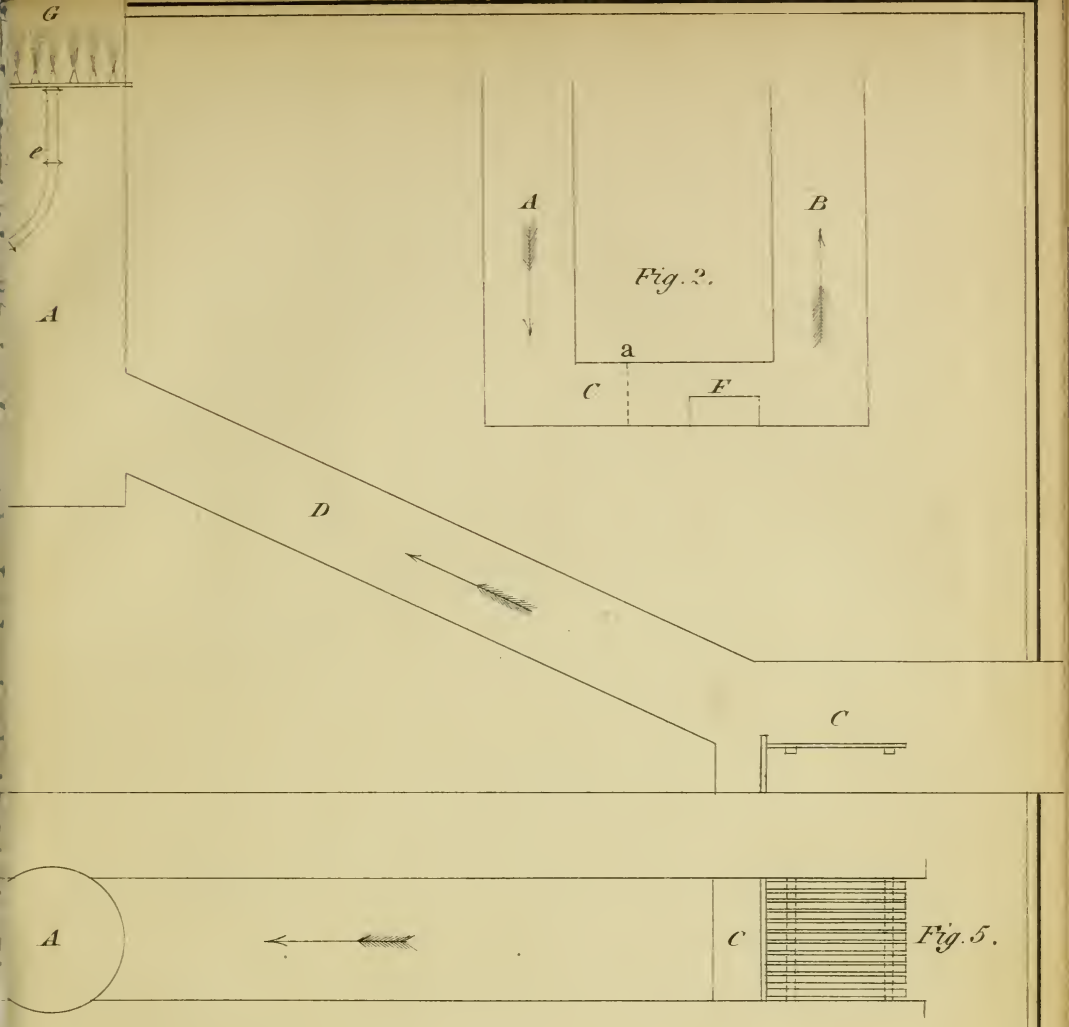


Fig. 5.

Fig. 7.

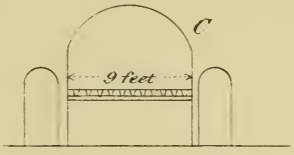
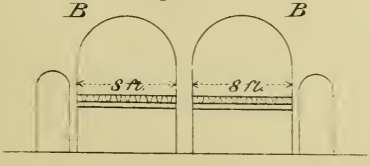


Fig. 6.



PLAN.

5 6 7 8 9 10 FEET

Newcastle.

PLATE II

Fig. 3.

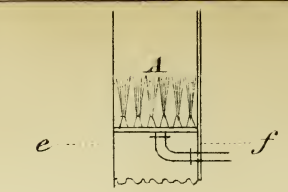
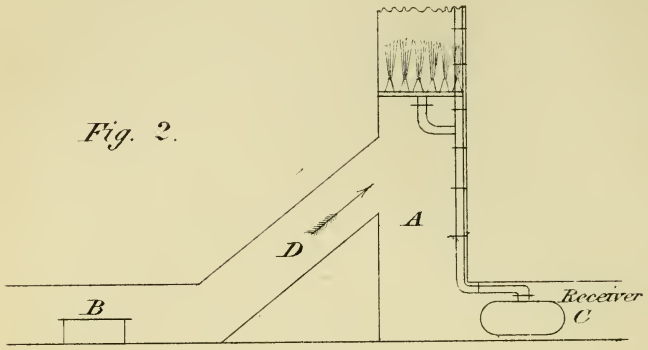
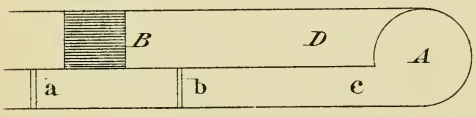


Fig. 2.





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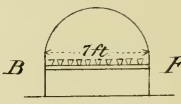

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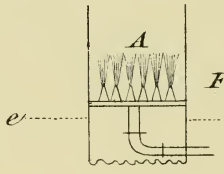
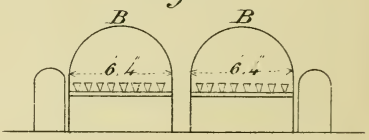


Fig. 8.

Fig. 9.



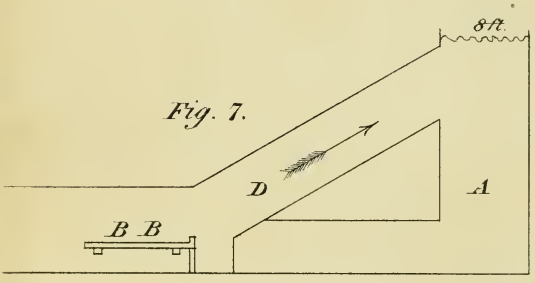


Fig. 7.

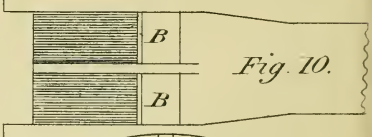


Fig. 10.

Fig. 11.

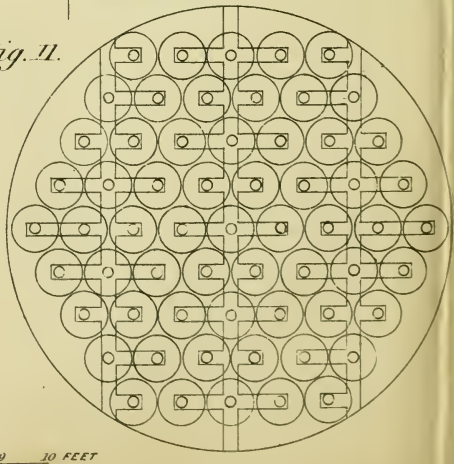


Fig. 6.

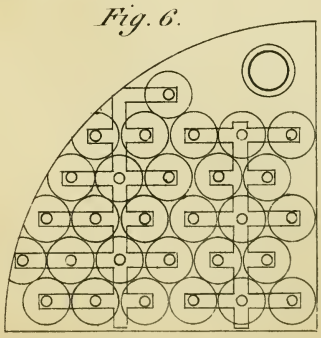
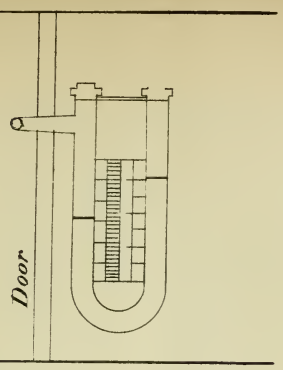


Fig. I.



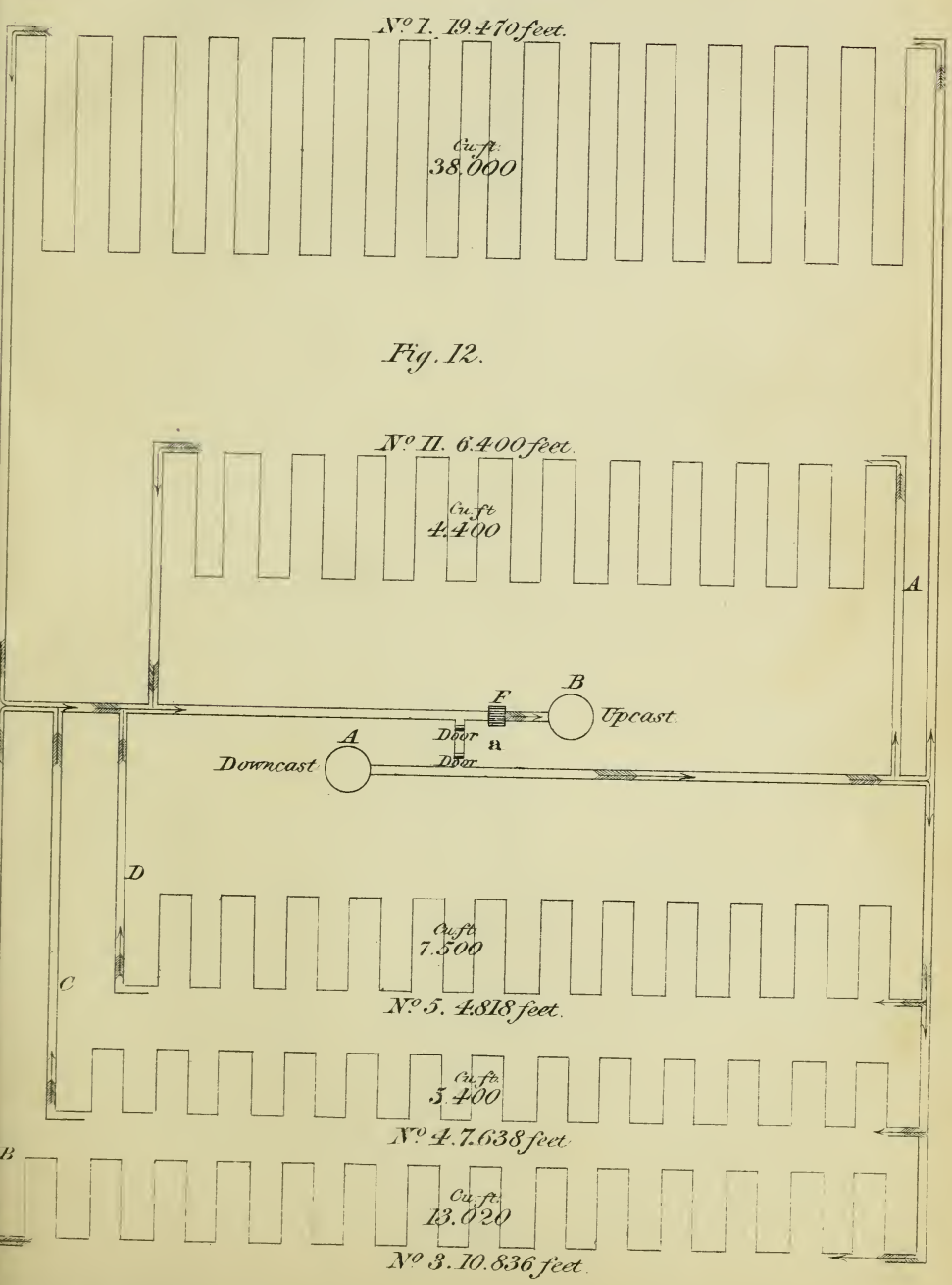


Fig. 12.

Lambert Jun. Newcastle on Tyne.

PLATE III.

Fig. 1.

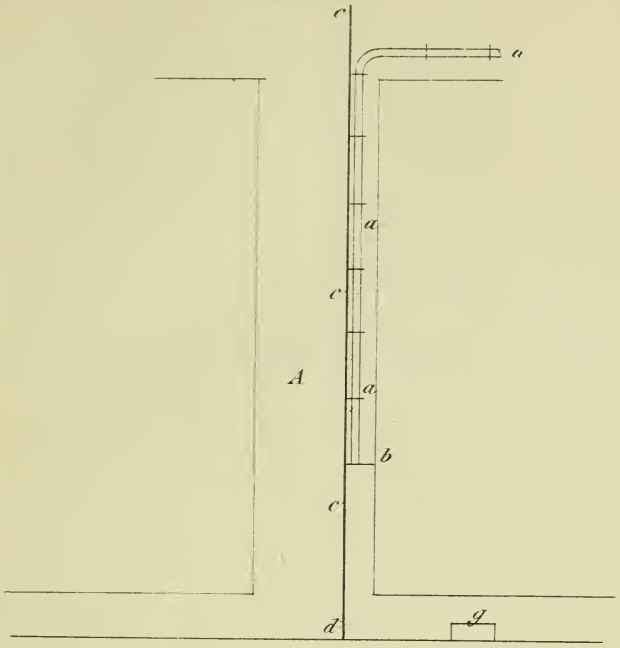


Fig. 2.

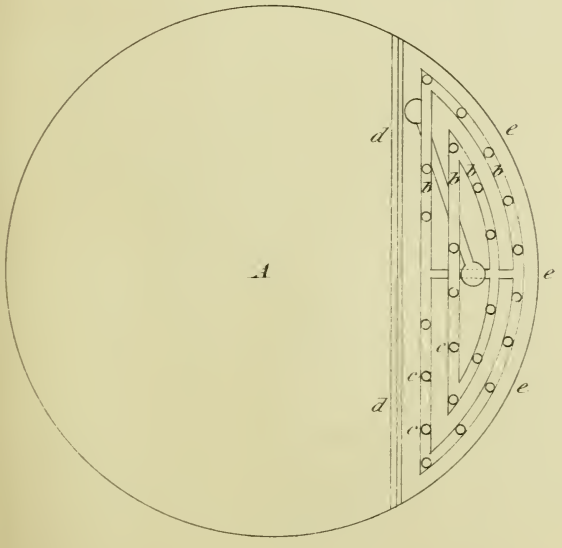
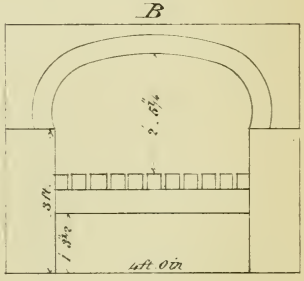
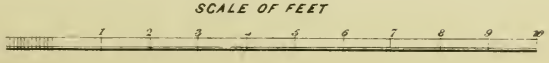


Fig. 3.

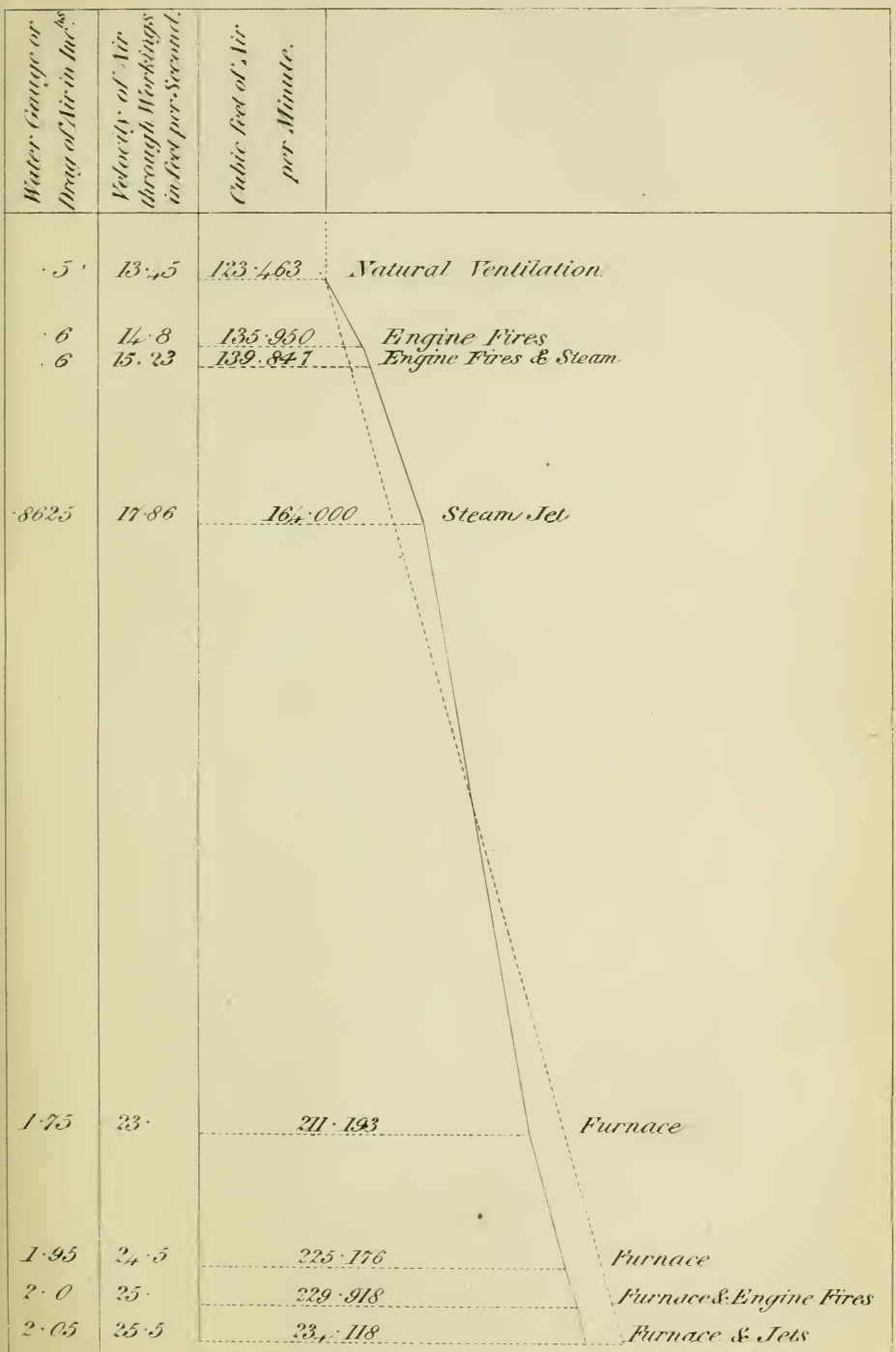


SCALE OF FEET



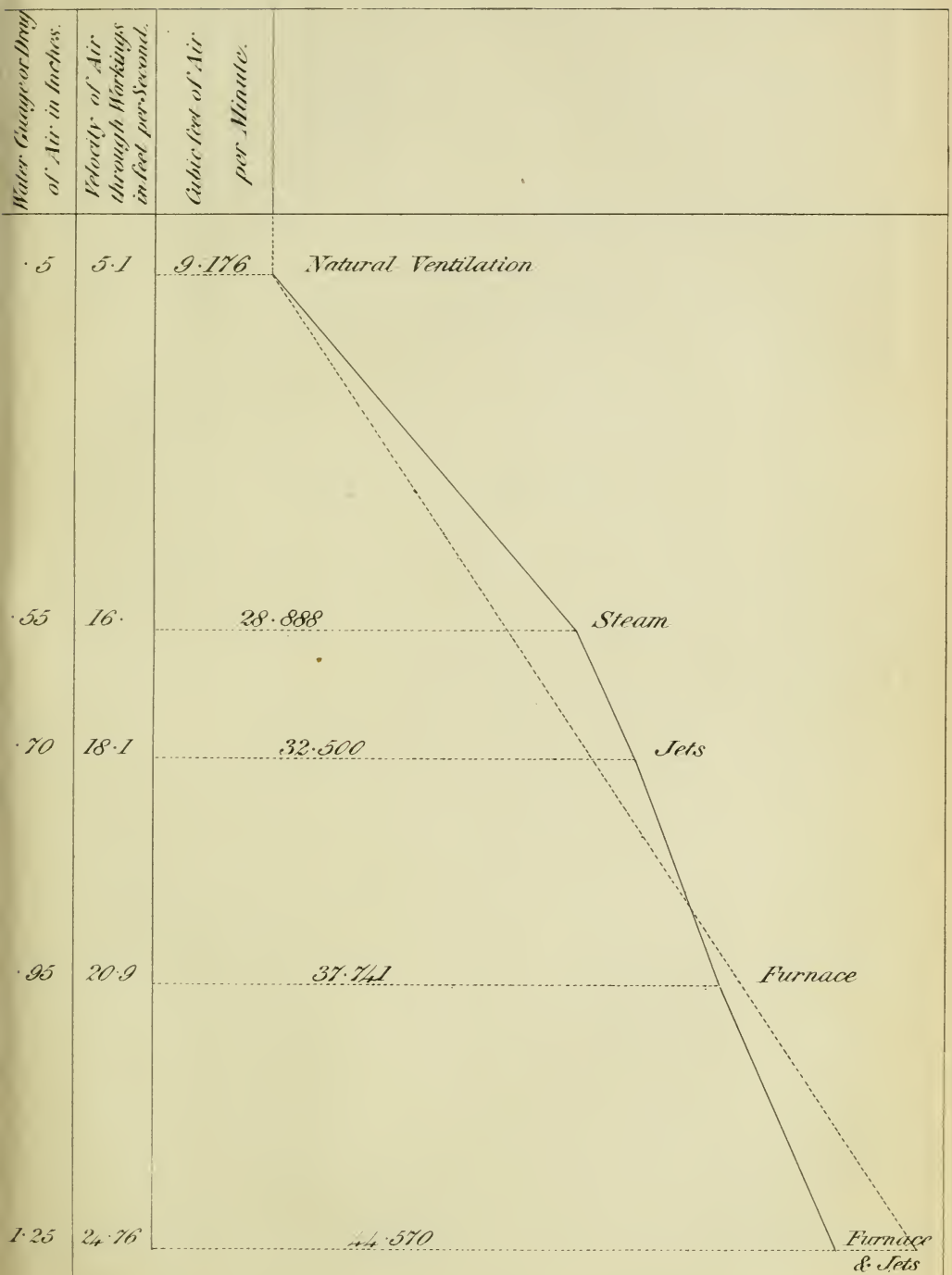
HETTON COLLIERY.

PLATE IV.



KILLINGWORTH COLLIERY.

PLATE V.



TYNE MAIN COLLIERY.

PLATE VI.

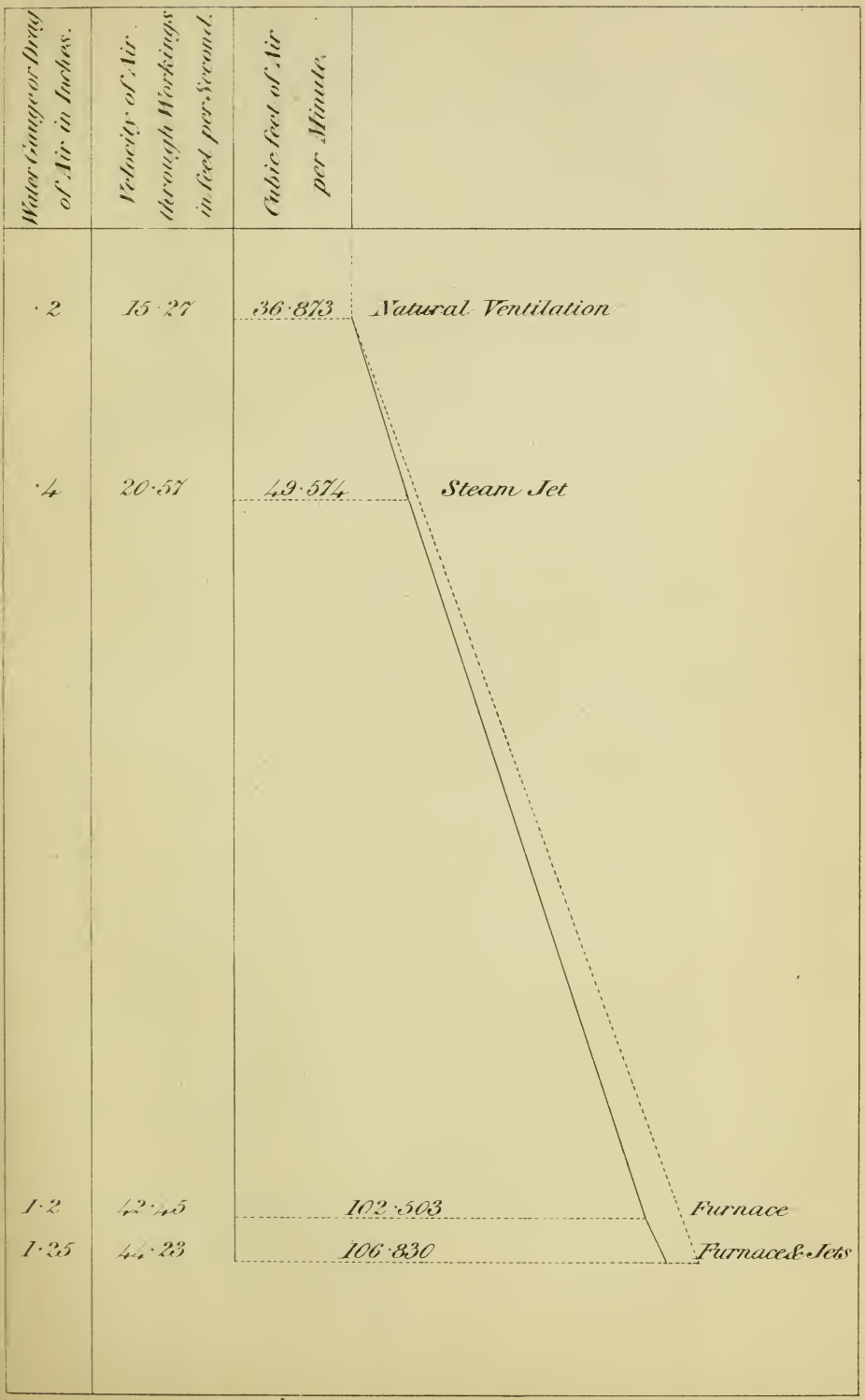
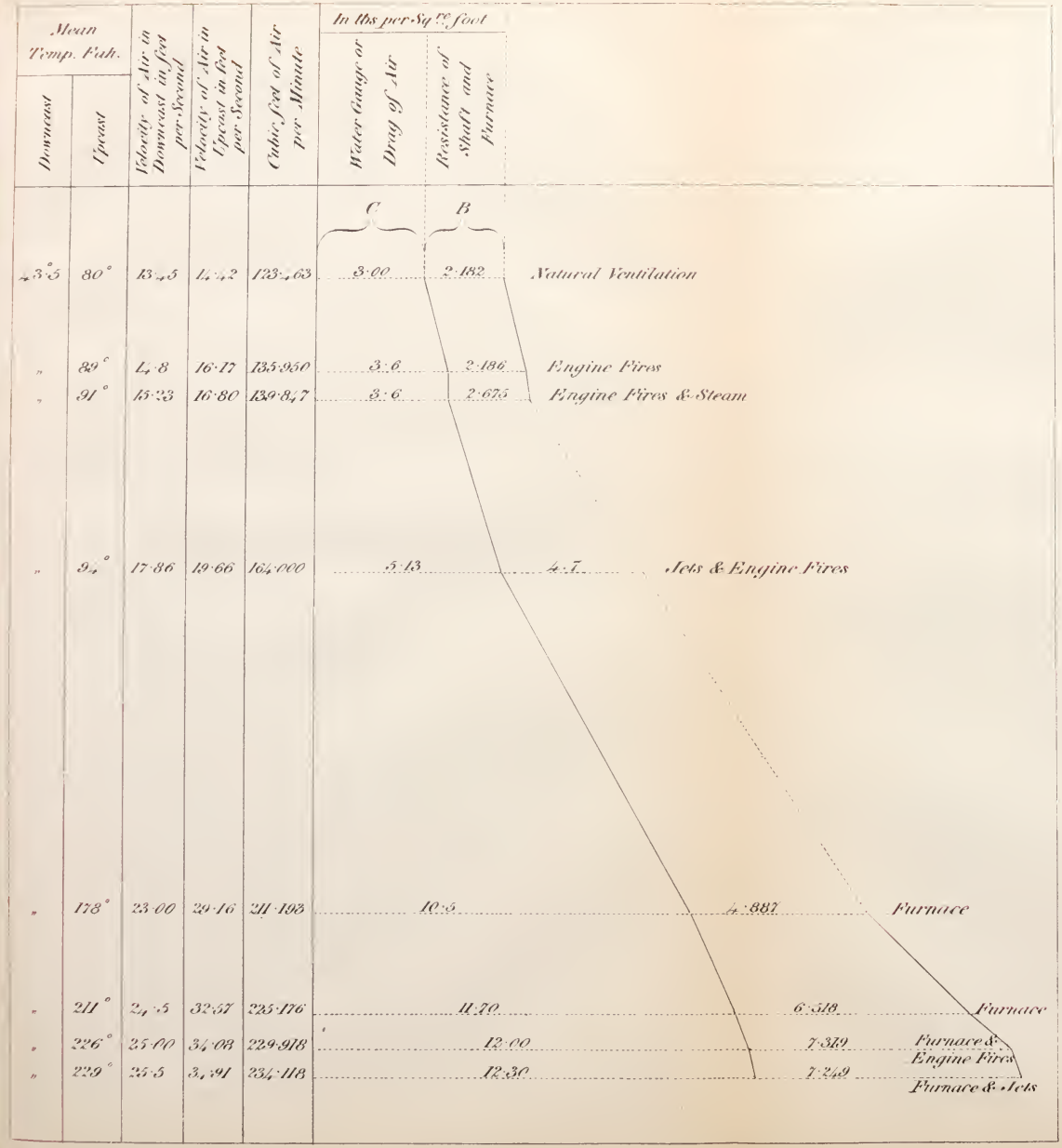


PLATE VII.

Mean Temp. Fah.		Velocity of Air in Downcast in feet per Second	Velocity of Air in Upcast in feet per Second	Cubic feet of Air per Minute
Downcast	Upcast			
43°·5	80°	13·45	14·42	123·463
„	89°	14·8	16·17	135·950
„	91°	15·23	16·80	139·847
„	94°	17·86	19·66	164·000
„	178°	23·00	29·16	211·193
„	211°	24·5	32·57	225·176
„	226°	25·00	34·08	229·918
„	229°	25·5	34·91	234·118

HETTON COLLIERY.

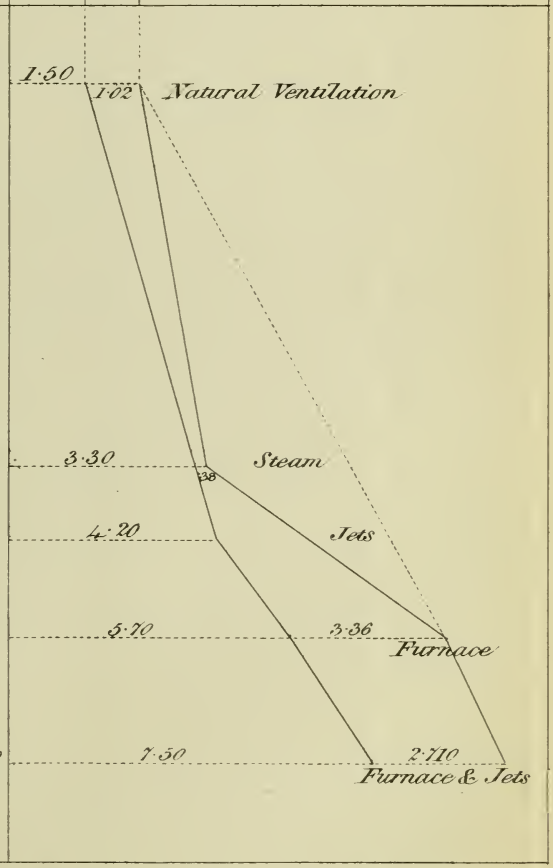
PLATE VII.



KILLINGWORTH COLLIERY.

PLATE VIII.

Mean Temp. Fah. Downcast	Mean Temp. Fah. Upcast	Velocity of Air in Downcast in F.t per Second	Velocity of Air in Upcast in F.t per Second	Cubic feet of Air per Minute	In lbs per Sq.re foot Water Gauge or Drag of Air	In lbs per Sq.re foot Resistance of Shaft and Furnace
49°	65°	5·1	5·26	9·176	1·50	1·02
"	88°	16·00	17·26	28·888	3·30	2·38
"	101°	18·1	19·96	32·500	4·20	
"	147°	20·9	25·93	37·741	5·70	3·36
"	164°	24·76	30·26	44·570	7·50	2·710

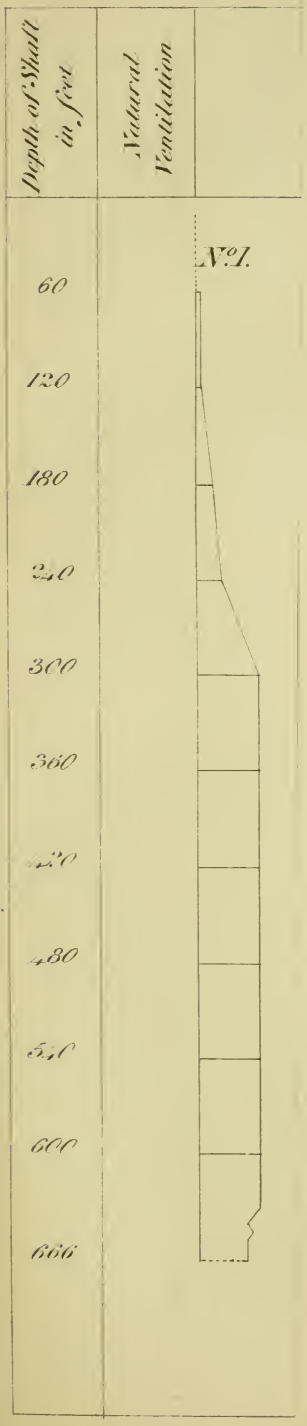


TYNE MAIN COLLIERY.

PLATE IX.

Mean Temp. Fah. Downcast	Mean Temp. Fah. Upcast	Velocity of Air in Downcast in Ft. per Second	Velocity of Air through Cylinders in Upcast in Feet per Second	Cubic Feet of Air per Minute	In lbs. per Sq.re foot: Water Gauge or Drag of Air	In lbs. per Sq.re foot: Resistance of Shaft and Furnace	
44°	62°	15·27	15·81	36·873	1·20	·604	Natural Ventilation
"	62°	20·57	21·11	49·574	2·4	2.	Jets
"	262°	42·45	61·04	102·503	7·2	8·477	Furnace
"	272°	44·23	64·48	106·830	7·5	8·65	Furnace & Jets

PLATE X.


Depth of Shaft in feet
Natural Ventilation
No. I.
60
120
180
240
300
360
420
480
540
600
666

KILLINGWORTH COLLIERY.

PLATE X.

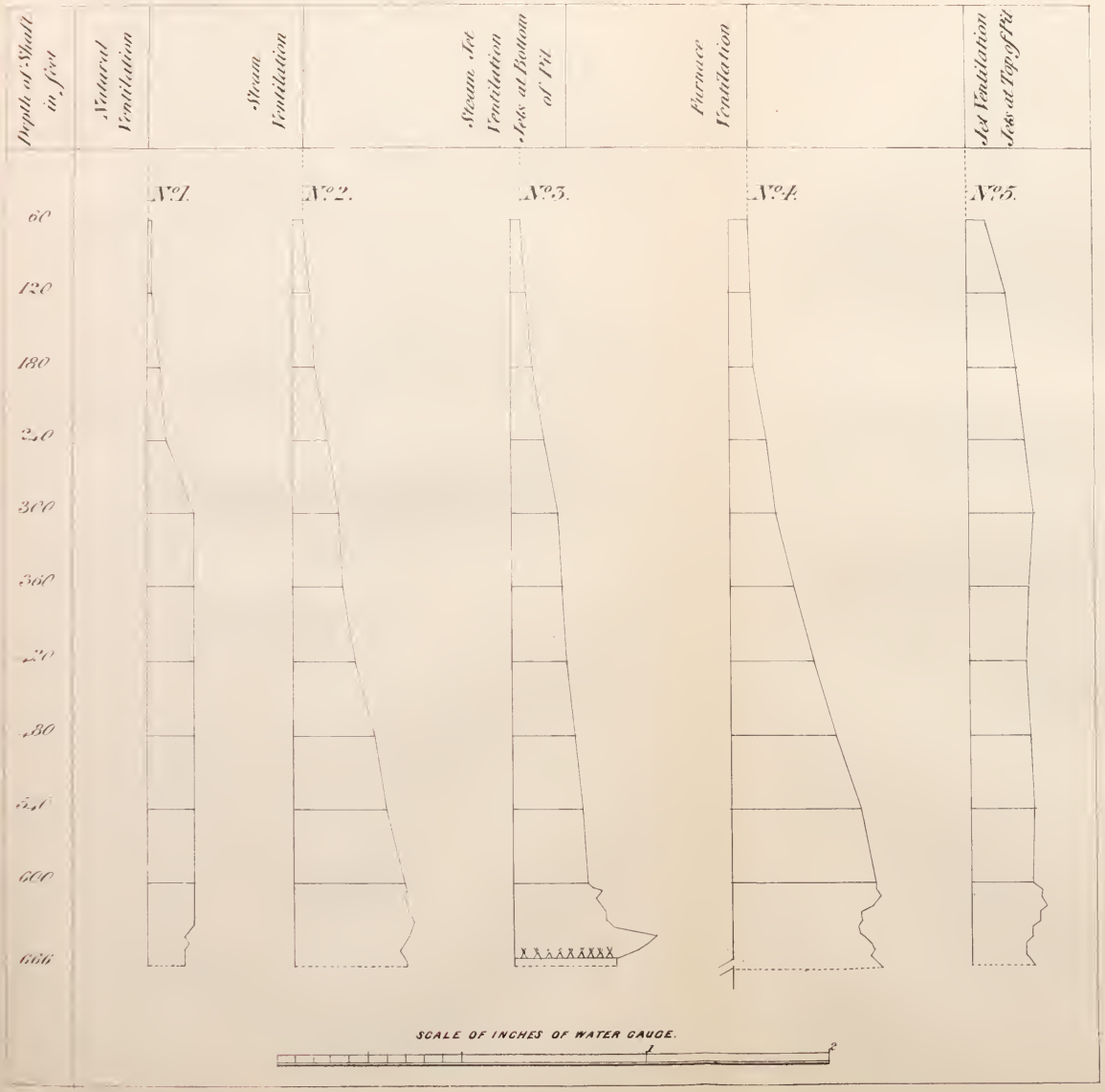
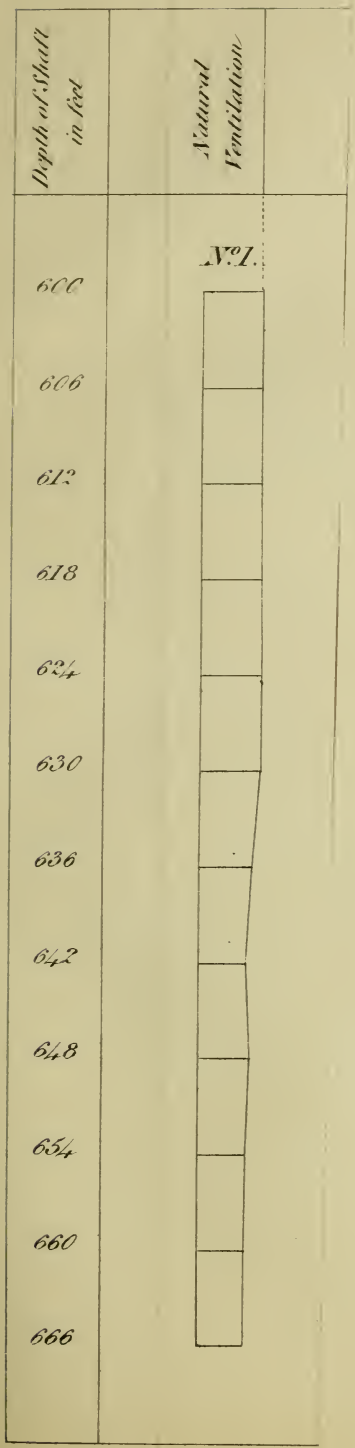
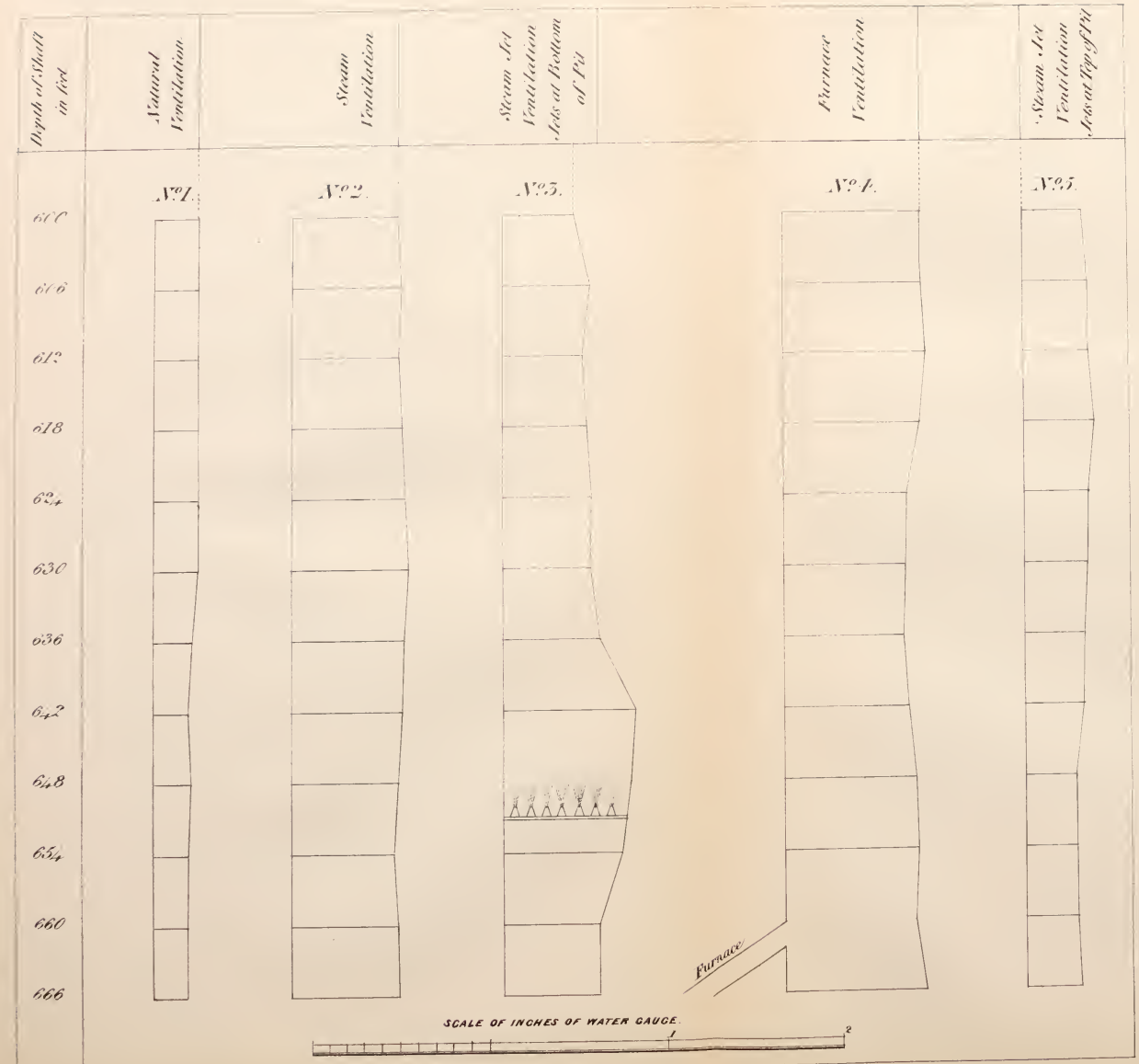


PLATE XI.

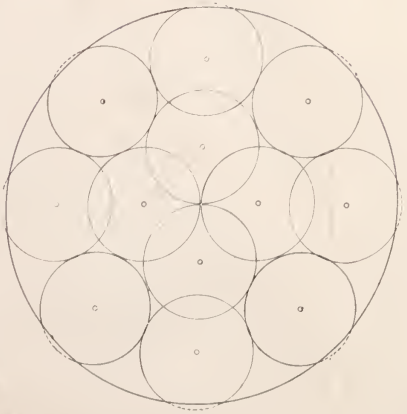

Depth of Shaft in feet
Natural Ventilation
No. I.
600
606
612
618
624
630
636
642
648
654
660
666

KILLINGWORTH COLLIERY.

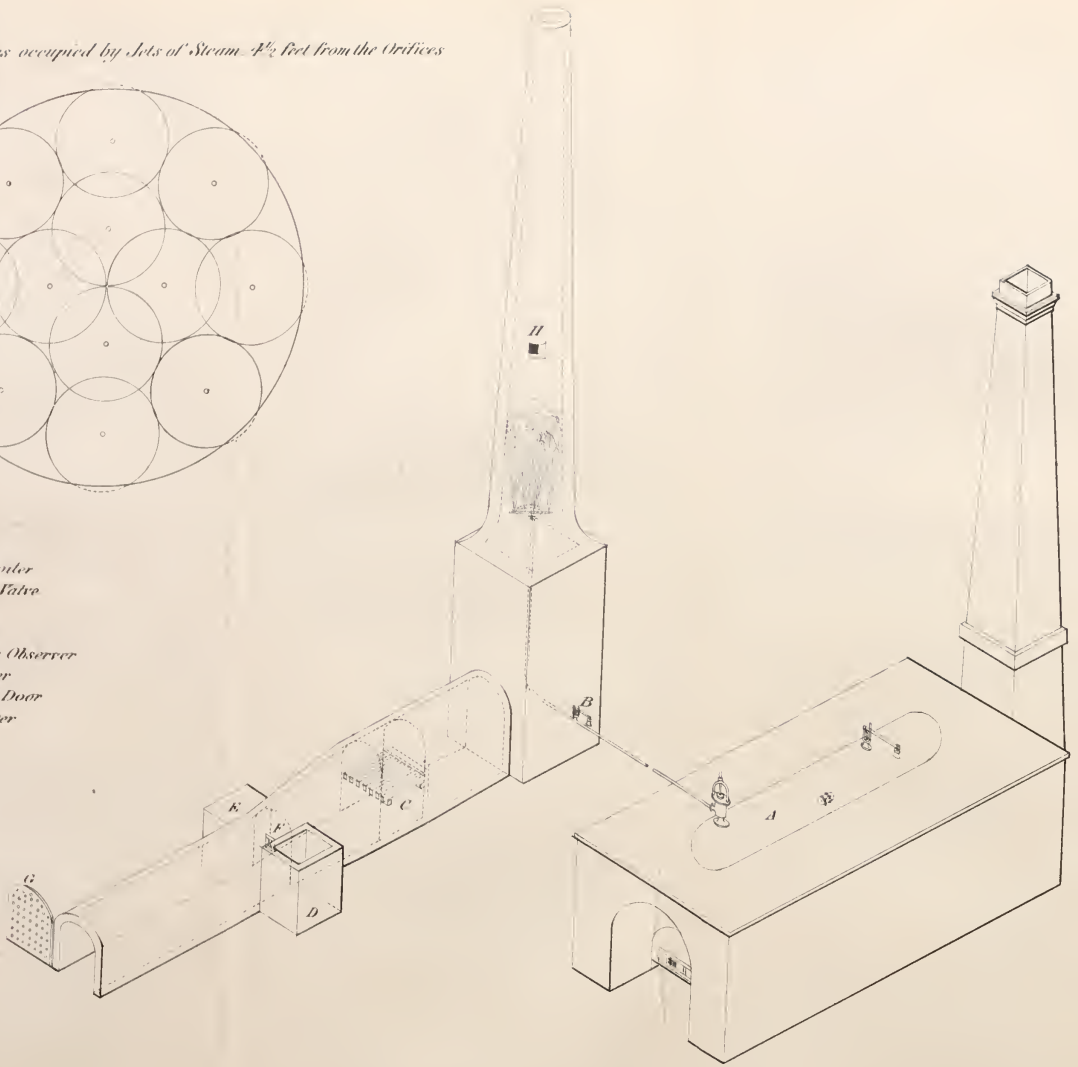
PLATE XI.



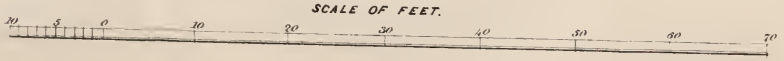
Plan of Spaces occupied by Jets of Steam 4½ feet from the Orifices

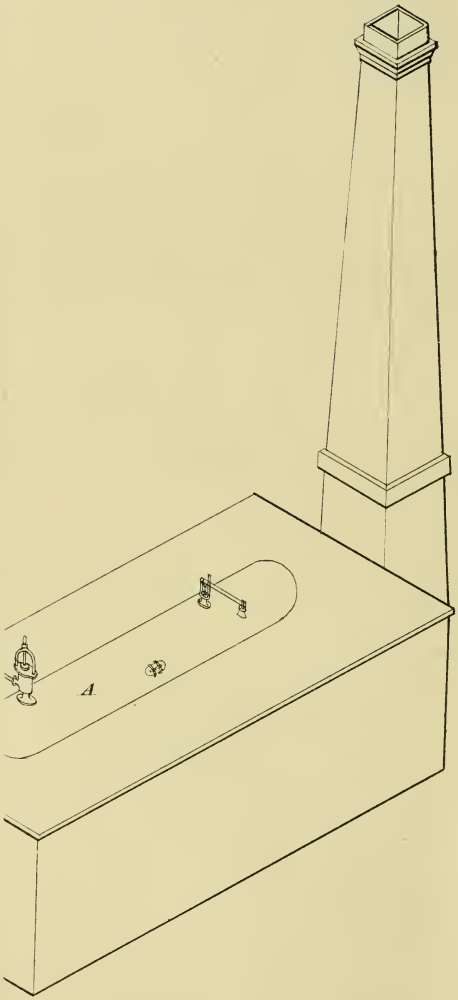


A. The Jet Boiler
B. Jet Safety Valve
C. Furnace
D. Coal Box
E. Recess for Observer
F. Anemometer
G. Perforated Door
H. Thermometer



SCALE OF FEET.





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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

AN ADDRESS

ON

THE RELATIVE VALUE

OF THE

FURNACE AND STEAM JET,

AS

VENTILATING POWERS,

READ BEFORE THE
NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS,
DECEMBER 13th, 1852,

BY

WILLIAM ARMSTRONG, JUN.

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1853.

EXPERIMENTS TO DETERMINE THE RELATIVE VALUE OF THE FURNACE, AND STEAM JET, AS VENTILATING POWERS.

The following experiments were instituted with a view to afford some practical data, to determine the vexed question whether the Furnace, so long the Ventilating Power in our Collieries, was capable of being assisted in its action by a Jet of Steam; or whether its future use might not be altogether superseded by the superior efficiency of the Jet itself, employed as the sole agent.

It occurred to me, that all the experiments hitherto conducted, had been defective in some one or other of those essential conditions, necessary to deduce the proper value of the two agencies. At first, it was perhaps natural to view with suspicion and dislike any innovation upon a favourite and old established method, and in despite of all disclaimer, we should not attempt to conceal from ourselves that some prejudice has been imported into the comparison, and under the influence of this pardonable bias, conclusions have been too hastily drawn, which a more impartial investigation, and a wider range of experiment, will tend materially to correct and modify.

We have had isolated experiments with the Jet conducted in the laboratory on a small scale,—illustrated in tubes of short dimensions, and results have been exhibited, very startling in their first impression. These effects have been most unfairly contrasted with those developed by the Furnace, rarifying air, which had passed through many miles of confined Air passages, in Shafts of all depths and every diameter, and as a matter of course from premises so dissimilar, and data so exceedingly unlike, most erroneous inferences have been drawn.

Experiments with the Furnace and Jet conducted separately, have also been made upon a large scale in the same shaft, but here again we are at fault; for on the one hand, the position of the Jet, the number of discharging orifices and their diameter, and their relation

to the area of the Shaft—and on the other hand—the size and position of the Furnace, have, it would appear, been determined from the mere accident of convenience, or the caprice of the experimenter. The utility of the results have still further been impaired by the limited period to which the comparison was confined, and the difficulty and danger to a working colliery in extinguishing the influence of the Furnace, and neutralizing its effects, before the Steam Jet was brought into play. These have produced, as might have been foreseen, a complicated and combined action, the indications of the Jet being in part referable to the residual action of the Furnace, which may either have crippled, or assisted its action.—And lastly,

Experiments with the Furnace and Jet together, limited however more or less with the defects before alluded to, combining either the exhausted steam from boilers—having other offices to perform in the mine,—or from independent boilers upon the surface, discharged either in a single Jet, or distributed over the shaft, with furnaces either in connexion with the underground engine, or separately for ventilation only.—Here again, the complication of effect from both without any attempt to assign the share due to either agency, or whether the two in united action, are not more effective than the sum of the two separately, have destroyed the whole value of the results.

It was clear, therefore, so long as the advocates of the Jet confined their defence to its speculative results in practice, deducible, either from data from the laboratory, or from hasty generalization from some one or other of the class of experiments above referred to, and wherein all the conditions of the problem were not fully and fairly taken into account; and the Furnace party, erring as much the other way, confiding altogether in their practice, and triumphantly pointing to the few facts of their limited experience, to the contrast they were enabled to show, in refutation of the labours of the mathematician and the theories of the philosopher; that so long as this state of hostility and self-reliance was permitted to continue, we should have in each session of Parliament the subject matter of difference referred to its Committee, who would either report with indecision, or arbitrarily, as the majority of the members might have their judgments biassed by the one side or the other; and the public—ever fault-finding—would continue to clamour for legislative interference, and deplore the default of science, to arrest the waste of human life.

One good, however—and this of no little moment—will result from the immediate labours of the Institute. The theory and practice of the best ventilating power within our present reach will ere long be completely and definitely established—and this settled and out of the way—the leisure of its members may be turned to other more minute professional questions of practice, until by repeated comparison and experiment, the standard of maximum safety under conditions will be arrived at. The dissemination of these most important desiderata throughout the district, will lead to improved discipline in our mines—a higher education of our officers—and as a necessary sequence, the improvement of our great staple trade—and above all, the diminution of risk to the life of our workmen.

With this view, and as a small help to other and larger trials, occupying as it were the midway position between the laboratory and the working colliery, I prepared an apparatus, which as far as practicable, should present to either agency—the Furnace and the Jet—circumstances and conditions precisely parallel,—capable of showing the effects of either without a chance of confliction, and equally competent to register the action of both in conjunction; for affected by the same disturbing causes, and retarded by the same hindrances, I cannot anticipate that the results—ascertained with considerable care—can be, under the particular conditions of the apparatus, other than a fair and legitimate comparison of their relative value as ventilating powers.

The chief points I sought to determine, were

1.—The most effective distance and space occupied by Jets of Steam of different sizes, and therefrom, the association of Jets in a given area, to produce a maximum effect.

2.—The dimensions of a Furnace, with the area above, and under the Bars, to give a maximum effect.

3.—The rarifying influence of the Jet.

4.—The ventilating power of the Jet arranged as determined in No. 1, under pressure of 30lb, 40lb, and 50lb, per square inch, with a contrivance, for imitating different values of the drag, or resistance to the air current in a Working Colliery.

5.—The Ventilating Power of a Furnace, arranged as determined in No. 2, and under like resistances.

6.—The Ventilating Power of a Furnace and Jet in conjunction with the Steam at the different pressures as in No. 4, and under like resistances.

And 7.—The economical features—the consumption of Coal, in the production of the different effects.

The experiments were conducted in a chimney possessing the following dimensions.

Height—80 feet.
Diameter at Jet apparatus—5 feet $2\frac{1}{2}$in.
Diameter at Top—3 feet.

The chimney having a regular taper, or conical form, for 59 feet, viz., from 21 feet from the bottom to the top.

Connected with, and opening into the chimney on the surface, is a drift or arching, extending 50 feet from the chimney, the internal area of which is exactly that of the largest area of the chimney, viz., 3068 square inches. In the drift, and 9 feet 4 inches, from the chimney, is a furnace 5 feet $2\frac{1}{2}$ inches wide, and 5 feet long, and within these limits, and over the fire, the internal area of the drift is enlarged, by the space occupied by the bars and coals—so that at all times, whether operating with the Jet or Furnace, there should be a similar area, through the drift into the chimney.

The Jet was placed 22 feet up the chimney, and within the conical part. Connected with the drift, and flush with its wall side, was a reservoir for coal, which had previously been weighed. Another recess was left for the observer, opposite whom was suspended on an immovable stirrup, a Biram's Anemometer. A door perforated with 525 holes of $1\frac{1}{3}$ inch diameter, distributed equally over its surface, whose aggregate area is equivalent to one-fourth that of the drift, and a Box 6 feet long by 1 foot square was nicely adjusted to the open end of the drift—the results show the effect of the drag or resistance, in passing through these reduced and divided areas. Doors having apertures of larger dimensions were tried, but currents of very varying

velocity were created in the drift—affecting the Anemometer very unequally, and tending to perplex the comparison. This was considerably, but not altogether remedied, by the improved arrangement.

A boiler, 29 feet by 6 feet, 4 inches diameter, having a separate chimney, supplied the Jet through a two-inch pipe, and the water evaporated, and coal consumed were carefully registered. Two safety-valves—the one upon the steam pipe outside the chimney—the other upon the boiler, served to check the pressure of the steam in use—and a damper, regulated the quantity of air, so as to avoid as much as possible any waste of fuel.

Experiments were first made to determine the evaporative power of the Jet boiler. Worked for 9 hours consecutively, and fired with some exertion—it was found, that an orifice in the Jet apparatus, having an area of one square inch, was capable of discharging the steam when pressed to 40lbs. per square inch. This pressure was indicated by both safety-valves. The bars and flues were clean—no water was admitted during the experiment, and the results may therefore be taken as a maximum.

The water evaporated was 44·88 cubic feet per hour—the heating surface being 229 square feet, and taking Tredgold's standard of 8·8 square feet surface for converting one cubic foot of water into steam, per hour, at a pressure of 40lbs. per square inch, as that practically to be assumed over-time, and as affording the necessary margin for the loss of effect in the water supply, and in the cleaning the boiler, flues, and fire, we have 26·023 cubic feet of water evaporated per hour, as the working power of a boiler of the above dimensions.

Assuming that the quantities of steam discharged will be as the areas of the apertures, we deduce from the maximum effect of the boiler, that its ordinary working evaporative power, is represented by a discharge pipe, having an area of ·58 square inch.

44·88 cubic feet of water, requiring 394·5lbs. of coal for its conversion into steam, is capable of being discharged through an aperture of one square inch; and inferentially, an aperture of ·58 square inch area, is the value of the evaporative power of a boiler, over-time, 29 feet long by 6¼ feet diameter.

It will be afterwards seen, by firing to extremity, that 60·83 cubic feet of water was evaporated per hour, and the pressure indicated throughout at the Jet safety-valve, was 50lbs. per square inch.

1.—As to the most economical and effective distance, and space occupied by a Jet of Steam.

In some experiments made by Professor Faraday on the Steam Jet, some few years ago, to ascertain the most effective size of the orifice, and the most economical, and effective pressure of steam—it was satisfactorily determined, that there was a close relation between the water evaporated to form steam, and the work done by that steam—the ratio being as exact as could be expected under the circumstances. Further—the effects from Jets with orifices of different diameter, were also ascertained to be nearly in the direct ratio of the sizes, but it was found, that more work was done in proportion to the quantity of steam as the Jet was reduced, so long as the bore was not so small as to occasion condensation at the orifice.

The maximum effect was attained, when a Box 18 inches square was employed, and the open end 12 feet, 11 inches from the Jet, the result with Steam at a pressure of 32lb per square inch being,

With a Jet having an orifice $\frac{1}{8}$ in. dia. —— 2056 Cubic feet per minute.
$\frac{3}{16}$ in dia. —— 3136 — do. — do.
$\frac{1}{4}$ in. dia. —— 4453 — do. — do.
$\frac{3}{8}$ in. dia. —— 6534 — do. — do.

I selected from these experiments a Jet of $\frac{1}{4}$ inch diameter as the most effective practical size, and from this Jet, at the pressure of 30lb, and 40lb. per square inch, I obtained trumpets or cones of Steam, possessing the following dimensions.

	Diameter of Cone.			
	30lb. per sq. in.		40lb. per sq. in.	
	ft.	in.	ft.	in.
At 2 feet from the orifice.....	0	9	0	9
3 ft.....do.....	0	10	0	11
4½ ft.....do.....	1	5	1	6
6 ft.....do.....	1	7	1	7

It appeared to me that the issuing steam preserved its compactness, or conical figure, to a distance of 4½ feet from the orifice, after which, the outline of the cone became less distinct; and in the distribution of the Jets within the area upon which I intended to operate, I apportioned the whole into areas, having diameters of 18 in., respectively allowing the different cones of steam slightly to overlap each other, so as effectually to fill the whole space. In this arrangement, therefore, I concluded that Jets of ¼in. diameter, and with the several cones of issuing steam, abutting on one another at a distance of 4½ feet from the orifice, each cone, at the several points of contact, having an area of 254·46 square inches, would afford the maximum effect. See Plan.

The area of the chimney where the Jet was introduced being 3067·9 square inches, it required 12 Jets to fill the entire space, the aggregate area of the expanded trumpets or cones of steam, being 3053·52 square inches. The orifices had brass mouths, accurately bored to ¼ in. diameter, their aggregate area being ·538 inches, and as the maximum evaporative power of the boiler was so much in excess, being in the ratio of 1 to ·588, there was abundant surplus to maintain the steam at any pressure. The Jet safety-valve, and that upon the boiler, gave on repeated examinations identical pressures, and there could be but little loss in the passage of the steam through the remaining short pipe, and apertures.*

* Each experiment throughout the whole series was continued for 6 hours, the revolutions of the Anemometer taken at the alternate ¼ hours, the velocity of the Air-current at similar intervals, and the temperature of the chimney every half hour. This was necessary from the discrepancies presented by other trials, wherein the observations were separated by longer intervals, and the irregularities reduced to an average. The tabulated results of velocity and temperature, are the mean of the observation of many experiments.

2. The position of the Furnace, with area above and below the bars, to produce a maximum effect.

In the determination of this point, the few experiments I made were not conclusive. The following sections were those selected, and the results are here tabulated.

	Feet.	Revolutions in 15 min.	Temperature. Drift.	Temperature. Chimney.	Coals per Hour. lbs.	Revolutions per 1 lb. Coal.
				o		
A. Area above Bars -	26·75	9010	52·7	320	303	297
below Bars -	8·75					
B. Area above Bars -	19·25	11255	38·	343	350	321
below Bars -	16·25					
C. Area above Bars contracted by Plate -	12·00	9087	43·5	350	379·2	239
below Bars -	16·25					

I selected, therefore, B. as presenting the most effective section of the three, without however determining it to be the best; and the following will afford the comparative effects of this section of Furnace, consuming different quantities of coal.

	Revolutions. in 15 min.	Temperature. Drift.	Temperature. Chimney.	Coals per Hour. lbs.	Maximum Cubic feet. Air per minute in Chimney	Cubic feet of Air to 1 lb. of Coal.
		o	o			
Barom. 28·5 Rain.	9091	39·4	226·6	251.1	14485	
	9085	56·3	243	233·3	16843	
	9450 } 9406	45 } 48·8	289·1 } 265·5	237 } 235·7	18544 }	4595
	9685·	45·3	264·6	237	16739	
	10012	41	320	256 6	17966	4209
	11255	38	343	350	19434	3331

These trials give a ratio between the coal consumed, temperature of the chimney, and the velocity of the air-current indicated by the Anemometer. The state of the weather, and Barometric pressure affected the results and account for the discrepancies; the fluctuations being very considerable.

The maximum velocity observed during any period of 15 minutes, was 20212 cubic feet per minute. which through the smallest area of the chimney gives 2832 cubic feet of air, for 1 square foot of area.

The diminishing effect from 1lb. of coal with the higher temperatures, as shown in this Table, is referable not only to the increased resistance under the known law to air at high velocities, but, to the contracting area of the chimney; for when it is considered that the difference of temperature between the ascending column and external air.

In the 3 Trials bracketted.....	is $216{\cdot}7^{\circ}$
5th Trial.....	289
6th Trial.....	305

we have, taking the ordinary formulæ of $\frac{459+t'}{459+t}$ for increase of bulk at temperature t', that of Air at the temperature t, being unity; the expanded volume of 1 cubic foot of air, due to those different temperatures as 1·42, 1·56, and 1·62 respectively. The law of resistance above referred to, will therefore oppose, (taking the temperature of so short a column as uniform to the top) not only the ratio of drag due to the increased velocities of the air, at the several diminishing areas in its ascent, but, these velocities will still further be augmented, by the enlarged volume of the heated air itself.

With the Furnace and Jet combined, the same increased retardation is caused, but in the Jet alone, the increase of volume of the air is so trivial from the heat of the chimney, that the effect of the latter, all other things being equal, should be relatively larger.

It may be, therefore, safely affirmed, that this particular form of chimney is adverse to the Furnace, and Furnace and Jet in conjunction, in any contrast with the Jet alone.

It must also be borne in mind, in contrasting the results from the Furnace, with those afterwards obtained from the Jet, that the column

of heated air being only 80 feet high, the effect from a given weight of coal is necessarily small, and that in point of fact, the comparison is between a Furnace with an 80 feet shaft, and a Jet, where the small elevation, may be confidently assumed as an advantage.

Taking Tredgold's formulæ for the velocities of air, with chimnies of different altitudes, we find, that irrespective of friction, the velocity of air entering Chimnies with elevations of 80, 600, and 900 feet to be 49, 135 and 166 feet per second respectively, having the temperature the mean of the three furnace trials bracketted, and assuming for the calculation, that this temperature is uniform in all the heights.

The maximum quantity of air obtained from 1lb. of coal, was when the chimney was at 237°,—the quantity being 4695 cubic feet,—whereas the average ratio of several Collieries reported by Professor Phillips was 12150 cubic feet to 1lb. This wide difference is clearly to be traced, to the causes above assigned.

No previous calculation would I think settle the most effective position and dimensions of a Furnace. Practice can alone assign them. If the area over the fire be too large, much of the current passes without suffering decomposition, and tends to lower the temperature of the upcast, but this again may be compensated by the smaller friction, to which the whole current may be subjected. Should the area over the fire be too small, a large portion of the air will be forced through the fire; more of it will enter into new combinations so long as the temperature of the fire through which it passes, is maintained at 1200°, the heat of the upcast will be augmented, and very anomalous results as to the ventilating current will be developed. It is clear that a maximum effect combining the condition of highest temperature in the upcast, with minimum friction, is attainable, and it would be well, if experiments were expressly instituted to solve so important a problem.

3. As to the rarifying influence of the Jet.

Much misapprehension has existed on this point. It has been a popular theory to attribute all the power of the Jet to this influence alone, and to disregard altogether its impulsive action, considering that the effect of the latter at the bottom of a shaft, and having a long column of highly elastic confined air to expel, will be almost neutralized.

The Jet has thus been treated as a mere substitute for the Furnace, and at first sight there is some cogency in the theory; for not only is the temperature of the issuing steam at a high elevation, but the condensed steam will naturally give out its latent heat. Steam at 40lbs. per square inch pressure, possesses a temperature of 288°, and the heat absorbed by the water in the production of the steam, is about 1287°; so that a given volume of steam, if all liquefied, and reduced to 82°, must have parted with 1205° of heat, and this all dispersed in the upcast, it was conceived would sustain the column at a high temperature, and irrespective of any impulsive action, possess a high rarifying power.

The velocity and quantity however of the ventilating cold current and the slow conducting power of air, were neglected in the estimate; and the following experiment determined, that within its limits, no material rarification is obtained—the temperature not being augmented, over a period of 12 hours.

Jet Apparatus, 50lbs. per square inch pressure.

	Temperature.	
	Drift.	Chimney
	°	°
6h. 0m. a.m.	47	79
	49	81
	52	81
	55	82
	56	82
	57	83
	56	84
6h. 0m. p.m.	54	82

The steam within the chimney was observed to be nearly all condensed into vapour, and the temperature, as indicated by the thermometer, was sensibly cold to the hand, and it is at once obvious, that from whatever cause the action of the Jet upon the column of air is philosophically to be referred, whether its action be analogous to an air

pump or force pump, it possesses some other power, that is attributable to the mere increased temperature it affords.

When however the Jet and Furnace are used together, the condensation of the steam was prevented by the high temperature due to the Furnace, and the smoke had almost entirely disappeared, caused in all probability by the deposition of the carbonaceous particles, from the diminished density of the air and steam combined.

To this circumstance of the steam being preserved from condensation by the heat from the furnace, is clearly to be referred the superior effect of the Jet and Furnace combined, as contrasted with the Furnace alone. When combined, it would appear that the impulsive action of the Jet, notwithstanding the products of combustion from the Furnace, had the effect of assisting the velocity of the air-current due to the Furnace alone. How far this superiority may be maintained in higher columns, where the power of the Furnace would be more developed, we are at present unable to say.

A question might in the first instance arise, whether the steam, being condensed, when the Jet was alone used, and therefore, by the contraction of its previous volume assisting its impulsive action, would not, although the watery vapour was to be raised to the height of the chimney, produce a better effect, then when used in conjunction with the Furnace; the chimney area being in the latter case occupied by air and steam, in a highly expanded state.

4, 5 & 6 { The Ventilating Power of the Furnace / ——do.——————of the Jet / ——do of the Furnace & Jet combined } and under different resistances.

The steam at the pressure of 30, 40, and 50lbs. per square inch respectively.

The more clearly to compare the powers, I have tabulated the results—the different expressions being the mean of all the experiments. In comparing the velocity of the air-current in the chimney, obtained from the Furnace and Jet together, with the Furnace alone, it was found that the revolutions of the Anemometer did not show corresponding differences, and this is accounted for by the fact, that to produce the same cold current, the steam and hot air when together in the chimney, must travel faster than the hot air, when alone.

The Anemometer will therefore show the ventilating currents

more accurately, and the Furnace indications have been taken as the standard.

Table A. Drift End open.

	Furnace.		12 Jets. ·25in. dia.			Furnace and Jets.		
	Maximum.	Average.	lb. 30	lb. 40	lb. 50	lb. 30	lb. 40	lb. 50
	o	o	o	o		o	o	o
Temperature of Drift	38	44	45·5	47	46	44·4	41·2	44·6
	o	o	o	o	o	o	o	o
——do.——of Chimney ——	355	281	71	76	85	288·4	301·3	304
Maximum Velocity of air in chimney--in feet per second	22·3	19	10·8	13·2	15·1	19	19·8	21·4
Do. Volume of air—in cubic feet per minute	20805	17651	10050	12292	14012	17628	18387	19931
Water evaporated from Boiler —in cubic feet per hour—	..	..	11·45	14 96	18·7	11·45	14·96	18·7
Furnace coal—in lbs. per hour	350	261	..	..	..	268·6	258·3	258·6
Boiler coal—in lbs per hour	..	..	113·6	139·5	175·6	113·6	139·5	175·6
Cubic feet of air--to 1lb of coal	3566	4058	5308	5287	4818	2767	2773	2741
lbs. of coal—to 1 cubic foot of water	..	..	9·92	9·32	9·39	9·92	9·32	9·39
Revolution of Anemometer in one hour	46030	39052	22236	27196	31000	39000	40680	44096

These trials show, that although the Jet alone gives a higher effect than the Furnace for the consumption of an equal weight of coal; yet that under our arrangement of the Jets, the quantity of air was much less; and notwithstanding that the ratio of increase at the pressures of 30, 40, and 50lb. per square inch was about uniform, the effect, reduced to 1lb. of coal, was less as the pressures advanced. This obtained throughout the whole of the experiments, and is intelligible on the principle, that a larger weight of condensed steam has to be raised when the Jet alone is at work,—and to the additional friction of the increased volume of steam, maintained at a high temperature by the ascending current of heated air, when in conjunction with the Furnace.

We also find, that the Furnace is slightly assisted by the Jet at pressures of 40lb. per square inch and upwards, as a mere mechanical effect, the relative values of the single, and combined action, reduced to 1lb. of coal, being considerably in favour of the former.

As the disposition of the Jets within the area of the chimney, is that generally considered as the most economical, we enlarged the orifice of each Jet to $\frac{2}{8}$in. dia. with a view to ascertain the effect when the coal consumed was nearly that of the Furnace; having pre-

viously ascertained, that the diameter of the cone of steam issuing from a $\frac{3}{8}$in. hole, was not appreciably larger than that from smaller apertures. The following Table presents results, as exhibiting the maximum effects of the Jet and Furnace.

Drift End open.

	Furnace.		12 Jets. of 375in. dia			Fur. & Jets.
	Maximum.	Average.	lb. 30	lb. 40	lb. 50	lb. 50
	o	o	o	o	o	o
Temperature of Drift	38	44	44	42	38·2	41·4
——Do.——of Chimney	355	281	92	93	96	309·6
Maximum Velocity of air in chimney—in feet per second—	22·3	19	15·5	19·7	21·08	24·9
Do. Volume of air—in cubic feet per minute	20805	17651	14444	18309	19586	23133
Water evaporated from Boiler—in cubic feet per hour	..	..	36·92	48·66	60·8	60·83
Furnace coal—in lbs. per hour—	350	261	..	..	.	310
Boiler coal—in lbs. per hour—	..	..	286·6	396·8	511·5	511·5
Cubic feet of air—to 1lb. of coal	3566	4058	3226	2770	2297	1690
lbs. of coal—to 1 cubic foot of water	..	..	7·27	8·11	8·41	8·41
Revolutions of Anemometer—in 1 hour	46030	39052	31956	40508	43334	51180

The aggregate area of 12 apertures each ·375 inches diameter, is 1·325 square inches, and with considerable exertion, the different pressures of steam in the table were maintained, the Jet safety-valve blowing off throughout each trial.

The Jet from the causes before alluded to, here shows a falling off compared with the Furnace; and although at the pressure of 40lbs. per square inch and upwards, the quantity of air obtained was about the same, yet the value of the effect reduced to 1lb of coal, is adverse to the Jet, and increasingly so, with the pressures.

In conjunction with the Furnace, the former superiority of mechanical effect in volume of air was maintained, but the consumption of coal was more than doubled to support it.

Taking 26·023 cubic feet of water as the standard evaporating power of the boiler, and 60·83 cubic feet of water having been boiled off to furnish steam at 50lbs. per square inch for this experiment, the working boiler power is represented by $2\frac{1}{3}$ boilers,—and taking the gross quantity of coals consumed by Furnace and Boiler, at 821lbs. per hour, we have an expenditure of fuel, equivalent to the power of a steam engine when working expansively, of 92 horse-power.

These trials had been made with the drift end open, and it became necessary to ascertain the relative effects of the two agencies, when the drift area was reduced, being equivalent to a larger resistance or drag. The perforated door was first used, and afterwards the area was still further contracted by the box, 1 foot square, and 6 feet long.

	Perforated Door.						Box in Drift end		
	Furnace.	12 Jets ·25 in. dia.		Furnace & Jets.			Furnace	Jets	Furnace and Jets.
		lbs. 30	lbs. 40	lbs, 50	lbs. 30	lbs. 40	lbs. 50	,,	lbs 50	lbs. 50
Temperature of Drift	o 39·4	o 50·5	o 49·9	o 49	o 39·8	o 41·7	o 40·1	o 35·3		o 39
Do. of Chimney	o 304·5	o 76·4	o 80·1	o 83 9	o 290	o 302·8	o 317·4	o 551·6	Current insufficient to maintain the Anemometer in motion.	o 529·4
Maximum velocity of Air in chimney—in ft. per sec.	15·9	6·6	7·5	8·4	16·3	16·7	17·7	4		4·17
Do. volume of Air—in cubic ft. per minute	14802	6169	6964	7765	15221	15530	16447	3731		3879
Water evaporated from boiler-in cubic ft per hour	,,	11·45	14·96	18·7	11·45	14·96	18·7	,,		18·7
Furnace Coal in lbs. per hour	232·5	,,	,,	,,	206·6	206·6	248	227·3		241·3
Boiler Coal in lbs. per hour	,,	113·6	139·5	175·6	113·6	139·5	175·6	,,		175·6
Cubic Feet of Air to 1lb. of Coal	3280	3258	2995	2653	2852	2692	2329	984		558
Lbs. of Coal to 1 cubic foot of Water	,,	9·92	9·32	9·39	9·92	9·32	9·92	,,		9·92
Revolutions of Anemometer, 1 Hour	32748	13650	15409	17180	33676	34360	36388	8256		8582

Great stress has been laid by the advocates of the Jet upon the elasticity of its power, and its independence of those conditions that militate so considerably against the Furnace, and ultimately counteract any further improvement of its effect.

Mr. Gurney, speaking of the Furnace, has designated some features of its action as paradoxical, and cautions against implicit reliance on its indications, they being in many instances deceptive. He sug-

gests a mode whereby the Furnace relieves itself from the difficulties to which it is occasionally exposed in getting air, by the natural insertion of an "imaginary aeriel plate of air in the upcast" when the resistances are so great, that the proper quantity of air "cannot come through the Mine to fill the exhaustion produced at the bottom of the shaft."

No such "paradox" is alleged to be connected with the Jet action, and the "Natural Brattice" is assumed to be impossible, from the power of the Jet being a constant quantity and independent of the current of air which it creates.

The above table however presents a very different and unexpected state of things, and was so unlike what was anticipated from the prominent advantages ascribed to the Jet in a diminished air course, that I was induced to repeat the experiments, but only to receive additional confirmation. The results are certainly *paradoxical*, for not only is the ventilating current with the Jet diminished relatively to the Furnace, when the Drift End was open and the resistance a minimum, but, the effect of 1lb. of coal, which in table A. shows an advantage in favour of the Jet is here reversed, and in every element of utility the Furnace has the superiority. The Jet and Furnace combined, however still preserved its former ratio of increase compared with the Furnace.

This is still more noticeable when the Drift was closed by the Box, being now $\frac{1}{20}$th of its former area, and the resistance to the air much augmented from this small size continuing for 6 feet. The Furnace and Jet, like the former trials, were still relatively more effective than the Furnace, at a largely increased cost of coal. *The Jet alone, did not produce sufficient current to cause the Anemometer to revolve.*

It is therefore clear that the effects of the Jet, mechanical and economical as compared with the Furnace, was higher under the small resistance afforded by the short and open-ended Drift, than when the Drift End was reduced to one-fourth its former area and the air made to pass through 525 small apertures. The relative advantages of the Furnace was still more apparent, when the air was confined to the box, and the current forced through a narrow passage 1 foot square and 6 feet long.

The "Furnace Paradox" is here fully illustrated. The higher temperature of the chimney is but the natural consequence of the less

quantity of air; the coals not being abated in the ratio of the current. Any other results than these would have been a "seeming fallacy."

It is also equally evident, that had there been any "Natural Brattice" during the high action of the Furnace upon the upcast column, that there must have been a very similiar phenomenon generated by the Jet. In both a considerable rotatory motion was observed in the chimney, the central part or axis ascending with a uniform velocity, whilst the side currents, rotating around the central one, progressed upwards irregularly, and at a slow rate, and not infrequently—when the box was further reduced in area—took a downward course.

And next as to its almost illimitable power. Professor Hann states "there is no limit, for all practical purposes, to the power of the Jet." Mr. Forster unhesitatingly affirms his belief, that "doubling the number of Jets, will be accompanied by double the quantity of air," and the distinction is perhaps still more forcibly put among the "Definitive technical explanations" of the "Commons" report of this year: for the Jet is there stated as "under the most perfect control, and is a more powerful agent when properly applied than the furnace—the furnace not producing more than 3 inches disturbance of the water-guage level—the Jet has been shown to produce 15 feet of water-guage."

Mr. Darlington asserts still more strongly "that there is *no practical limit* to the power of the Jet, being almost capable of producing a vacuum;" whilst Mr. Mather, finding no type in nature within the temperate regions, has recourse to the phenomenæ of the tropics, and speaks of it superlatively as a "tornado of a power," sweeping away in the plenitude of its might, every contamination to a wholesome atmosphere.

We think it must be apparent to any one from this language, that the advocates of the Jet limit its power only by the practical application of boiler power; every additional Boiler, every additional Jet adding its rateable contribution of effect. If the speculation be pursued to its extreme limits, it will thus stand.

We have seen that a boiler capable of supplying a ·58 square inch hole with steam, issuing at a velocity as will be afterwards shown of 648 feet per second, and we have therefore only to attach a boiler to every equivalent section of shaft area, to convert the shaft into the eduction pipe of a high-pressure engine. Taking 14 feet diameter as our

largest upcast, 38200 Boilers would, assuming the arrangement practicable, be necessary before this condition of things was fully realized.

At what point between the application of the Jet in its most economical form, and the complete occupation of the shaft as an eduction-pipe with the exhausting steam, the mere maximum effect would be realized, it is of course impossible to say. Possibly, an intermittent action, like the blast pipe of a locomotive engine, might be found to afford higher quantities than the continuous issue of the steam.

We think it however very probable that the limit of maximum effect would soon be reached. In these experiments, we find that the relative capabilities of the Jet at 50lbs. per square inch with apertures whose areas are 1 : 2·25 were 14012 : 19586 in volume of air current; the effect reduced to 1lb. of coal being as 4818 : 2297 or an improvement of 39·8 per cent of effect at an expence of 191 per cent increase of fuel, and this inverse ratio would go on increasing, until the further occupation of the shaft by the steam would reduce the current to a feeble quantity, and before long extinguish it altogether.

We are aware that objections may be taken to the conical form of the chimney, and its effect in dimishing the force of the Jet, by the additional friction to which the steam must be exposed in its egress; but the heated air from the Furnace, is as I have shown, equally if not more affected by the same cause, and as the height of the chimney, contrasted with the depth of such of our collieries as require a large ventilating current is inconsiderable, the results may from this very retarding section, approximate more closely to those which would have been realized had the chimney been higher, with a uniform cylindrical area.

As the difference in the weights of the descending and ascending columns constitutes the motive force of the Furnace,—the deeper the shaft, the greater the power and circulating current. Fortunately, the coal seams most subject to gas discharges, are the lowest members of the section, and here the Furnace is most available.

The high temperature generated in the upcast, is communicated to the shaft, strata, walling, and metal tub, and these being good conductors of heat, tend to equalize the irregularities in the rate at which the Furnace is fired, and render still more valuable service, in the preservation of a slowly decreasing ventilating current, in case of negligence.

The steam Jet is however deficient in not having in reserve this accumulated power, and in its unassisted action, it is probable the air current will be at all times variable, and not infrequently liable to be altogether suspended, rendering necessary a constant vigilance and close attention, which it is most desirable should, in performing so very important a function in colliery practice, be avoided.

As the effective action of the Jet is attributable to the rapidity of the issuing steam; we think it obvious the lighter the column that is propelled before it, whether consisting of air, or watery vapour, and the sooner it is dispersed in the open atmosphere, the better.

Perhaps, a position of the Jet so as to admit of the exhaustion of the steam at the top of the chimney, precisely where the cone becomes irregular in its outline, and its force impaired, would afford a much higher standard of effect than in any other position, and certainly would be more effective than the situation recommended by its advocates, at the bottom of the shaft.

Approximately, the velocity of the steam issuing through a Jet, at 40lbs. per square inch, would be, taking the formulæ —

$v' = v\left(\frac{459+t'}{459+t}\right) =$ 1904 the volume of steam when discharged at 40lbs. per square inch

t' its temperature

t the temperature, and v the volume of steam 1711 at the pressure of the atmosphere.

and as the difference in the height of two columns of steam having volumes of 1904 and 1711 respectively—water being unity—is 6562 feet, and adopting the expression $8\sqrt{h}$, we have 648 feet* as the velocity of discharge in feet per second, whilst the mean velocity in the chimney, deduced from the revolutions of the Anemometer, is but 20 feet per second.

Strictly, the comparison should be instituted between the velocity to which the steam is reduced at the distance of $4\frac{1}{2}$ feet from the Jet, yet between its velocity at this point and that of its mean ve-

*The velocity calculated from the water evaporated is higher than is furnished by the formulæ, being 905 feet per second. This discrepancy may be owing to the difficulty in exactly defining the volume of the steam, at the point of discharge.

locity in the chimney there is still so remarkable a loss of power that the best position of the Jet is too self-evident to admit of further illustration.

The only utility of its position at the bottom of the Pit is in the very inconsiderable rarifying influence it possesses, due to a difference of temperature of some 40° or 50°, but this can in nowise compensate for the loss of mechanical effect when so placed. Nothing is more easy to provide against, than the fissures of the surface alluvium, to which Mr Gurney alludes, as almost his only argument for removing the Jet to the bottom of the upcast.

And we think it even questionable, where underground engines are in use, and the depth of the shaft exceeds 400 or 600 feet, whether the loss of power, in the propulsion of the eduction steam through small orifices, and the necessary increased wear and tear of the boilers from having to be maintained at a higher pressure, will be compensated by the insignificant increase in many instances, and in the most favourable and extreme cases, but trivial improvement in the air current, derived from the substitution of a Jet apparatus for the ordinary waste pipe, as an auxiliary to the Furnace, if the latter be but judiciously applied.

Doubtless, many instances may occur, where the Jet may be attached as a useful adjunct to a Furnace, and may afford valuable aid in the opening out of new winnings or old wastes where air courses are limited. It may also be advantageously employed where Furnaces are inadmissable; and the experienced viewer in the course of his practice, will be enabled to recall many occasions, where its use would have saved much anxiety and outlay.

It is not however in these comparatively rare and exceptional cases, that the two agencies ought to be compared. It is in the ordinary condition of a colliery, conducted on the most approved principles, with full freedom and scope for the introduction either of the Furnace in its best proportions and situation; or the Jet under its most favourable features and with none of those extreme causes present, to incline particularly to the one or the other, that these experiments are intended to have special reference, and these observations are I submit fair matter of inference.

The general conclusions we would draw are the following.

1. In shafts of all depths, the consumption of an equal weight of coal will produce a higher ventilating current from the Furnace than the Jet.

2. That the difference in favour of the Furnace when the Jet is placed at the bottom of the shaft, will be increased as the depth, but in a higher ratio—the longer column, adding to the exhausting power of the Furnace, and diminishing that of the Jet.

3. That in the production of equal currents of air, the Furnace is the more economical agency of the two.

4. It is probable that in all shafts, where the temperature is sufficiently high to preserve the steam from condensation, that a larger mechanical effect—a larger volume of air will be obtained when the Furnace is assisted by the Jet—the consumption of coals however being largely increased.

And lastly.—That the Jet except in conjunction with the Furnace, and whether placed at the bottom, or top of the shaft, is, from the liability to sudden stoppage and irregularity of motion incident to all machines, unfitted for the very important function of ventilating our deep and extensive collieries.

WILLIAM ARMSTRONG, Jun.

Wingate Grange Colliery,
Nov. 1, 1852.

W. AINSLEY, PRINTER, SADDLER STREET, DURHAM.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

COUNCIL MEETING, FRIDAY, DEC. 31ST, 1852, IN THE COAL TRADE OFFICE, NEWCASTLE-ON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

It being desirable that complete experiments should be performed for the purpose of testing the capabilities of the Steam Jet for Ventilating purposes.

Resolved,

That the next General Meeting of the Society be postponed until Friday, February 4th, by which day a full account of the experiments is expected to be ready, and that the various papers and communications on the subject be read on that day, and printed as soon as possible afterwards with a view to the Members of the Society being furnished with copies previous to the General Meeting, on the 4th of March, which is appointed for the discussion of the subject.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING ON FRIDAY, FEBRUARY 4, 1853.

DURHAM:
PRINTED AT THE CHRONICLE OFFICE, 67, SADDLER STREET.

1853.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

GENERAL MEETING IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, FRIDAY, 4TH FEBRUARY, 1853.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meetings having been read, Messrs John Hedley, Joseph Smith, Francis Stanier, William Greene, Jun., Henry Plews, Thomas Murray, John H. Hunt, and Robert Hawthorn were elected members of the Society.

The PRESIDENT then said that Dr Glover had submitted for the inspection of the members of the Institute an improved safety lamp; and, as that gentleman was present in order to explain the principles upon which his lamp was constructed, he thought it would be desirable to dispose of that business first. He would, therefore, with the approval of the meeting, request Dr Glover to proceed with such explanation as he was prepared to offer. The subject was not only interesting in a scientific point of view, but it was one which came peculiarly within the province of the Institute to investigate; and was, besides, one of the highest importance in mining operations. After Dr Glover had given his explanation, he should be happy to listen to the observations any of the members might think proper to make upon it.

Dr GLOVER, exhibiting a lamp constructed on the principle he recommended by Mr Cail, Optician, Newcastle-upon-Tyne, said :—I shall not occupy your valuable time unnecessarily by attempting to say much to

parties so well acquainted with the subject as you are, but shall proceed at once to point out the peculiar merits of this invention, which is the joint production of Mr Cail and myself. We have worked together from the beginning, and I, therefore, deprecate its being called my lamp. Without any further observations on that point, I shall now proceed to make a few practical remarks; and, in the first place, I would remark that anything like abstract protection from gas is entirely out of the question. I will shew you why. When we burn gases that are highly explosive, such as carburetted hydrogen and oxygen, we use a brass tube such as I now hold in my hand—(about six inches in length and half an inch in diameter). It is filled with wire, packed tight, and through the centre of it a brass pin is driven home. With such an instrument as this, I have burnt oxygen and hydrogen repeatedly, at the risk of my life should an explosion have occurred; and I may, therefore, say it contains the principle of perfect safety. I believe Sir Humphrey Davy himself stated that, where there was gas, his lamp was not safe in a current. I know there are doubts upon that point, but, dealing with it as an admitted fact, we set to work to ascertain how it could be cured. Now, the great defect of the Davy lamp is, that it does not give a sufficient amount of light. These lamps are used where, otherwise, candles should be used, on account of the deficient light of the Davy. Now, we do not contend that our lamp is a perfectly safe one, for, as I said before, we have not to deal with a perfect safety lamp; but we do contend that it is greatly more safe than any at present in use. In this lamp we have a double cylinder of glass, the outer one being a quarter of an inch in thickness; and between these cylinders there is placed a double wire gauze, through which the air passes to feed the flame. If the outer glass should happen to be broken, the lamp would continue to be a safe lamp. Another advantage this lamp possesses is, that it becomes extinguished in a very explosive atmosphere. It is also a good test lamp, for it soon exhibits those appearances so well known among miners as indicating the presence of carburetted hydrogen. It is hardly necessary for me to remark that a double cylinder is much stronger than a single one, and that if one should be broken the lamp would be a safety one for a time. I have received reports from several gentlemen who have tried this lamp; but, as most of them are present, it is not necessary for me to occupy your time in stating their opinions, which are generally favourable. I have received one unfavourable report, however; but, as the conclusion arrived at is contrary to my own observations, and those of others, I cannot but think there has been some mistake committed in the course of the experiments. I have

no intention to press this lamp upon you contrary to your own convictions; you are the best judges in the matter, and I leave it entirely in your hands.

Mr Croudace.—How is it that the lamp becomes extinguished in a very explosive atmosphere?

Dr Glover.—The fact has been ascertained; it is not the result of my own experiment, and I must, therefore, decline to give an explanation. Upton and Roberts's lamp and Stephenson's also go out.

The President.—The reason why the lamp goes out is, the diminished quantity of air which gets into it being unable to support combustion. This lamp is very like Stephenson's in principle. The air enters through the wire gauze, and when it becomes highly explosive there is not sufficient oxygen present to support combustion, and it consequently goes out.

Dr Glover.—When a large quantity of carburetted hydrogen is mixed with the atmospheric air the lamp goes out.

Mr T. Y. Hall.—Yes; but it first explodes within the lamp.

Mr Reed.—This lamp is somewhat similar in principle with Stephenson's, but it will burn for a longer time than Stephenson's; it does not go out so soon, and that is an advantage.

The President.—I do not think it an objection to a lamp that it goes out. I rather consider it a principle of safety in Stephenson's lamp that it goes out in a very explosive atmosphere. I do not think any mine ought to be worked when the lamp goes out. This lamp will admit more air than Stephenson's does; but, the quantity being still limited, the light will become extinguished at a certain point.

Mr Armstrong.—As I am one of the persons alluded to by Dr Glover, I may state that I quite satisfied myself from experiments made in all gases that this lamp is self-extinguishing.

The President.—Will you explain whether that is on the same principle or not as Stephenson's?

Mr Armstrong.—The principle in that respect is the same, and it is extinguished on the same principle as Stephenson's.

The President.—After the oxygen is consumed the air left is not fitted to support combustion, and the light goes out.

Mr Armstrong.—Yes; but you are aware that, if the lamp be put into an explosive mixture when the light goes out, the combustion of the gases goes on. This lamp is, in point of fact, the same in principle in that respect as Stephenson's, but it has two glasses.

Dr Glover.—I would wish you to state, Mr Armstrong, whether or not you consider it to be a practical lamp, because Upton and Roberts's and others are not capable of being practically used.

Mr Armstrong.—I think it rather a complicated lamp, because it is composed of so many parts—six or seven parts—and, therefore, from the complication of its parts, I say it is objectionable for general use among the workmen; but as a deputy's lamp, or an overman's lamp, it is not an objectionable, but a superior one. I object, first of all, to its being of glass, and second, to the complication of its parts.

The President.—We are very much indebted to Dr Glover for exhibiting the lamp, which exhibits great ingenuity in its construction. But, somehow or other, I cannot get over the feeling that lamps not protected by gauze are perfectly safe. I must confess, I would like to see the lamp covered with gauze outside. Still that is no objection to the lamp, as compared with Dr Clanny's and others; I think, in fact, it is an improvement upon Dr Clanny's lamp; I think the principle of going out a very good one.

Mr Elliott.—I wish to say a word in defence of Dr Clanny's lamp. I have had a good deal to do with it; and I would feel obliged to Dr Glover if he will point out how his lamp is superior to Dr Clanny's in light, safety, or in self-extinguishing.

Dr Glover.—I have great respect for the abilities of Dr Clanny, and I was, in fact, the person who presented a testimonial to him in Sunderland, but I do not think his reputation is at all involved in this question. The simple question is, whether or not this lamp is an improvement upon his; not only in having a double cylinder, but in the passing of the air between the two. I can assure Mr Elliot he may hold this lamp in his hands for hours, when he could not do so with Dr Clanny's.

Mr T. S. Hall.—It seems to be exceedingly well made, and very portable. I think it a very good lamp.

Dr Glover.—The principle upon which Dr Clanny went was this:—he supposed, and there is a diagram representing his idea in a report of Dr Reid's, that the air to feed the flame came down in converging curves, and went off from the flame in diverging curves; both having much the same form, but differing in direction. That was his idea, and what he considered the great merit of his lamp. Now, any lamp having holes at the bottom simply does away with that principle.

Mr Elliott.—I am, perhaps, unduly partial to the Clanny lamp; but, at the same time, as the subject is before the meeting, I think it but fair to state that I have worked with it for several years—six or eight years. I have employed several hundreds of them; and in no case have I been made acquainted with a single instance where the safety of the miner has

been imperilled by any accident to the glass. We have a large increase of light from it; and, with respect to the circumstance of which Dr Glover complains, I will only say you may take a Clanny lamp and sit with it until doomsday, and it will not become heated, unless where there is a very large quantity of gas.

Mr Easton.—The cause of their getting hot is, that the lower meshes get clogged. If they are kept clean, they remain perfectly cool. We use them at Hebburn, and we find no difficulty, except what arises from putting a somewhat complicated instrument into the hands of a coal-hewer. The great difficulty we meet with arises from the fact that the men, unless carefully watched, suffer them to get very much out of order.

Mr Anderson.—I beg to propose a vote of thanks to Dr Glover. I cannot speak as to the merits of the lamp, but we are certainly very much obliged to him for the lamp he has exhibited here to-day.

Mr Easton.—I second the motion.

The President put the motion, and it was carried unanimously.

Dr Glover.—On behalf of Mr Cail, and for myself, I beg to thank you for the honour you have done us.

Dr Glover and Mr Cail then retired, leaving the lamp they had exhibited in the possession of the Institute.

The President then read a continuation of his former paper on the comparative merits of the Furnace and the Steam Jet in the ventilation of Coal Mines. After reading it, he said he hoped to have the paper printed in the course of a fortnight, and it was the intention of the Council to have the discussion upon it at the next meeting of the Institute. He had hoped that to-day they would have had some communication from Mr Elliott. Mr Barkus had also a paper on the same experiments. It would be desirable to have all these documents before them before going into the discussion. There was likewise a paper from Mr Taylor, detailing some experiments made at Holywell Colliery, of forcing air down the shaft by steam jets.

Mr Elliott.—I think those papers will not be in the hands of members sufficiently long to enable them to enter into the discussion of them at the next meeting. Would it not be better, therefore, to adjourn the general discussion until the meeting after next? However, if that is not approved of, I think it desirable that printed copies of the papers should be sent to the members as soon as possible.

The President.—The Council think it desirable that the discussion should take place before Parliament meets. You are aware that a Committee of Inquiry is to be moved for, and it may be desirable to give evidence

before that Committee on the subject, in which case it would be better to have the discussion previously.

Mr Dunn.—Would it not be practicable to have all the papers ready for distribution in a fortnight?

The President.—I am afraid not, for we have not received the whole of them yet. The experiments have extended to a much greater length than was anticipated.

Mr Elliott.—I do not think the experiments which I have conducted will go further than those of Mr Wood, but I would wish for my experiments to be incorporated with the general experiments made with respect to steam ventilation. I would remark that the general experiments have gone to shew, first, that furnace ventilation, with the same consumption of coal as that with the steam jets, is greater than that produced by steam—I do not say how much, but considerably more than with steam; and, second, that the quantity of air is much greater with the steam and furnace together than with the furnace alone. There are a great many facts that have been elicited with respect to temperature, but it is not necessary the meeting should listen to them at present. These experiments will be permanently recorded in the archives of the Institute, and may be referred to by future members.

The President.—It would be desirable to have the acccount of your experiments printed along with the others, because they were made at pits of less depth. My experiments were made at the depth of 150 fathoms, and yours, I believe, at about 60 fathoms. The experiments made by Mr Greenwell were in a shaft of 40 fathoms deep. He erected the steam jets at a depth of 30 fathoms, and in that way he got more air by means of the furnace than by the jets, although the shaft was only 40 fathoms in depth. It would be very desirable, therefore, to have all these experiments set forth in conjunction with those made in deep shafts. The Council, and Mr Taylor particularly, thought it desirable that the discussion should take place at the next meeting. At the last meeting of the Institute of Civil Engineers, a paper was read by Mr Joshua Richardson upon the subject. I was present on the occasion, and the members thought it very desirable that our discussion should take place as soon as possible, so that the subject should receive a full discussion under the most favourable circumstances for eliciting the truth. I told them what was going on here, and they agreed to defer the remainder of their discussion until they had an opportunity of ascertaining what we were doing. But there was a general feeling that the discussion should take place before any parliamentary measures should be taken on the

subject. If you postpone this discussion for two meetings, that will bring us to April. I, therefore, think it better, under all the circumstances, that the discussion should be taken at the next meeting.

After some further conversation, it was arranged that Mr Elliott should prepare his paper against the next meeting, and that the discussion should be commenced immediately after it is read.

The meeting was then adjourned.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

EXPERIMENTS

TO DETERMINE

THE RELATIVE VALUE

OF

THE FURNACE AND STEAM JET,

AS

VENTILATING POWERS.

COMMUNICATED TO THE

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS,

ON FRIDAY, 4TH FEBRUARY, 1853.

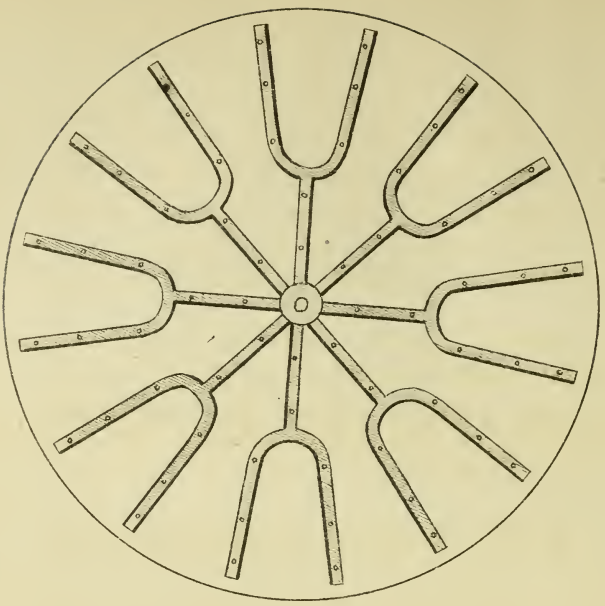
BY

WILLIAM BARKUS, THOMAS JOHN TAYLOR, AND MATTHEW B. ROBSON.

Durham :

PRINTED AT THE CHRONICLE OFFICE, 67, SADDLER STREET.

1853.

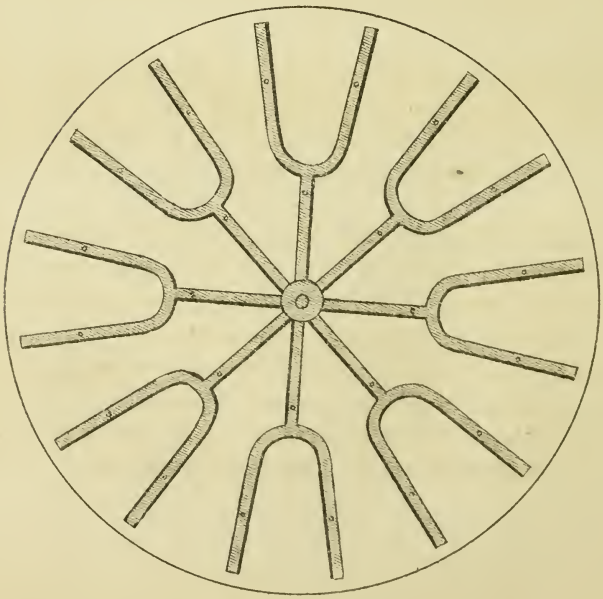


PLAN OF STEAM JETS

IN

ALLERDEAN WEST PIT,

Scale ⅛ Inch to a Foot.



ON

FURNACE AND STEAM JET VENTILATION.

BY WM. BARKUS, OF TEAM COLLIERY.

3RD FEBRUARY, 1853.

MR. PRESIDENT AND GENTLEMEN,

My object in appearing before you on the present occasion, has arisen in consequence of the numerous advocates that have made their appearance, to take part in discussions on the superiority of Steam Jet Ventilation when compared with the Furnace.

The limited experiments that I have to lay before you, were made under feelings entirely free from party or prejudice, being induced in consequence of having within reach, at a small cost, the means, at Team Colliery, to test the two contending claims fairly.

I have been employed in Coal Mines upwards of 50 years, and as a Colliery Viewer since 1811. I have had the management, during the latter part of this period, of several extensive Mines—some of which may be fairly considered as dangerous—and feel it a duty due from me to bear testimony to the existing system of Furnance Ventilation, as being, in my opinion, superior to any other method yet discovered; and by means of which I have been enabled to perform arduous and occasionally dangerous duties, without having lost a single life by explosion.

I need not remind the Colliery Viewers present, who have had the direction of Mining operations where accidents have occurred to cause the loss of life, how frequently they have been branded with severe censure by parties entirely uninformed of the nature of such misfortunes, the dread of which ought to be considered sufficient to incite any man possessed of ordinary feelings to do the utmost in his power to avoid such calamities.

My object in becoming a member of this Society has been purely with a view to endeavour (with the assistance of my brethren of the profession) to find out improved methods of management; more particularly in order to obtain greater safety by an increase of Ventilation, and to point out the inapplicability and danger of introducing false theories when they present themselves.

I feel most grateful to those scientific gentlemen who have taken a part in assisting to promote our views; and trust that our discussions, when brought before the public, will have the effect of shewing that we have not been inattentive to the safety of our fellow-beings, with whom we are equally exposed to danger, and that we are not so entirely destitute of scientific knowledge as has at times been ascribed to us by parties in the metropolis.

The apparatus by means of which the following results were ascertained, remains attached to the Boilers and Steam Jets, and may be examined by our excellent President and Vice-Presidents of the Institute, together with our respected Mine Inspector for the district, at any time on due notice being given.

It was intended to proceed with those experiments to a greater extent; but, in consequence of the Pumping Engine being so heavily laden with water during the late wet season, we have been prevented from having the use of the Boilers.

DESCRIPTION OF

EXPERIMENTS MADE AT TEAM COLLIERY,

FOR THE PURPOSE OF TESTING THE

RELATIVE VENTILATING POWERS OF THE STEAM JET AND THE FURNACE.

3RD NOVEMBER, 1852.

These Pits were selected, one a Downcast, and two separate Upcasts, in one of which Steam Jets were fixed, and in the other the Furnace; provision being made to shut off the Upcasts entirely from each other.

In order to equalise the depths of the Pits as nearly as was practicable, a tight scaffold was put into the Downcast and Steam Jet Upcast, at the level of the Seam in which the Furnace is placed. The depths stood as follows:—

	Fms.	ft.	
Downcast	22	2	to the top Coal-Seam.
Steam Jet Upcast . . .	25	1	
Furnace do.	44	2	

Diameter of each Pit, 7ft. 9in.- Area, 47 feet.
Area of Air-way, 10.5 feet, or nearly one-fifth of area of Upcasts.
Distance from Downcast to Furnace Upcast, 308 yards.
Do. do. to Steam Jet do., 183 yards.

The first Experiment was made in order to ascertain the number of Boilers required to supply the Jets.

Three Boilers applied, each 21 feet by 6 feet, were sufficient, with quick firing, to supply the Jets at a pressure of 30lbs. per square inch.

Steam Pipes, leading to Jets, 3in. diameter, 7.068 in. area.

67 Jets, each 0.17 in., or nearly three-sixteenths of an inch diameter; aggregate area, 1·52 in.

Jets placed at 27 feet from top of Pit.

Before the Jets were put in operation, there was a natural current passing from the Downcast to the Steam Jet Upcast of 7,560 cubic feet per minute, as measured by the anemometer, which may probably have been caused by the previous heating of the Upcast Shaft.

EXPERIMENT No. 1.—TABLE 1.

Five Boilers attached, and a plentiful supply of Steam furnished to the Jets, at a pressure of 30 lbs. per square inch, measurements of air taken by Biran's anemometer—see Table.

After the above Experiment, the Jets were allowed to blow off for half-an-hour—steam at the same pressure.

Five observations, taken with the anemometer, and the same result obtained.

Steam raised to 35 lbs. per square inch.

No increase obtained to the quantity of air.

Reduced the number of Jets from 67 to 25, and the Steam to 25 lbs. per square inch pressure.—Result, see Table 1.

No. 2 Experiment shews a loss of 2,741 cubic feet per minute.

Closed off Steam Jet Upcast, and opened a communication through the same Airway to the Furnace.

Measurements taken by anemometer—see Table 1, No. 3 Experiment, which shews an increase of 6,741 cubic feet per minute in favour of the Furnace.

10TH NOVEMBER, 1852.

Experiments resumed.

Length of Air-way to Steam Jet Upcast increased from 183 to 1827 yards.
Do. do. to Furnace do. „ „ 308 to 1777 „
Depth of Downcast increased from 22 to 62 fathoms.

Upcasts, area of Air-ways and Steam Jets, remain the same as in the former Experiments.

EXPERIMENT No. 4. TABLE 1.

In this experiment, more Boilers were applied than were necessary to supply the Jets; and it would, therefore, appear that a greater quantity of Coal would be consumed than was required to pass the quantity of air given in the table.

With two Boilers applied, and with very hard firing, the Steam in the discharging pipe was maintained at a pressure of 28.8 lbs. per square inch, during 1 hour and 15 minutes.

Weight of Coal consumed, 9.6 cwt. per hour, being 2.4 cwt. more than the consumption of the four Boilers. It may, therefore, be fairly assumed that three Boilers would be required to supply the Jets with Steam, at a pressure of 30 lbs. per square inch, with moderate firing.

One Boiler applied (Steam blowing through same area of Jets).

At the end of 15 minutes, Mercurial Guage fell from 29.12 to 24.0 per sq. in.
„ 30 do. do. „ 23.0
„ 45 do. do. „ 22.5
„ 60 do. do. „ 22.0

Weight of Coal consumed, 4 cwt.

It will be observed that the quantity of air passed through the increased length of air-way was reduced from 11,613 cubic feet to 2,310 cubic

feet per minute, being a loss of 9303 cubic feet, or in the ratio of 566 cubic feet for each 100 yards of increased run.

EXPERIMENT No. 5.—TABLE 1.

Furnace.

With the increased length of run, the quantity of air passed was reduced from 18,354 cubic feet to 12,520 cubic feet per minute ; being a loss of 5,834 cubic feet, or in the ratio of 397 cubic feet for each 100 yards increase of run.

EXPERIMENT No. 6.—TABLE 2.

Steam Jets enlarged to 0.25 in. diameter Aggregate area, 3.28 in.

Five Boilers applied—Mercurial Guage on the blast pipe maintained at 25 lbs. per square inch.

Steam blowing off at the Jets 30 minutes before the measurement of the air was taken.

With the enlarged Jets, the quantity of air was increased from 2,310 cubic feet, to 3,675 cubic feet per minute.

EXPERIMENT No. 7.—TABLE 2.

Furnace.

Closed off the Steam Jet Upcast, and opened the communication to the Furnace—length of run and area of air-ways remaining the same.

Quantity of air passed, 13,500 cubic feet per minute ; being 9,825 cubic feet per minute more than was obtained by the Steam Jet. With quick firing, the quantity was raised to 14,600 cubic feet per minute.

Date of Experiments.	No. of Experiments.	GENERAL REMARKS.	Cubic Feet of Air per minute passed to the Upcast.
			Cubic Feet.
1852.		STEAM JETS.	
Nov. 3.	1.	Diameter of each Pit, 7 feet 9 inches Area of ditto 47 feet ... . Area of Air-way leading to the Upcast, 10·5 feet..... 67 Jets, each 0·17 inch. diameter, placed at 27 feet from Top of Pit..... .... Aggregate Area of Jets, 1.520 inches... Blast-Pipe, 3 inches diameter, 7 inches area.....	11·613
„	2.	25 JETS APPLIED	8·872
„	3.	FURNACE APPLIED .... Area, 10 feet by 3 feet 3 inches ..... Area of Air-ways and Length of Currents, same as above	18·354
		STEAM JETS.	
Nov. 10	4.	Area of Air-way and Pits remain the same as above ..... Boilers, 21 feet by 6 feet ..... 67 Jets, each 0·17 inch. diameter, Steam blowing through Jets 30 minutes before measurements were taken...	2·310
	5.	FURNACE APPLIED ..... Same as in No. 3 experiment as above	12·520

TABLE I.

EXPERIMENTS WITH THE FURNACE AND STEAM JET.

Date of Experiments.	No. of Experiments.	GENERAL REMARKS.	Depth of Pits.			Temperature of Pits.		Length of Air Currents.		Number of Boilers applied, each 21 feet by 6 feet.	Effective Pressure in Boiler, indicated by Safety Valve.	Effective Pressure on Blast Pipe, indicated by Mecurial Gauge.	Water Vaporized per hour.	Coal consumed during Experiment.	Coal consumed per hour.	Coal consumed per c. Feet of Water Vaporized.	Quantity of Air passed per pound of coal consumed.	Velocity of Air Current.	Water Gauge.	Duration of Experiment.	Cubic Feet of Air per minute passed to the Upcast.
			Downcast.	Furnace Upcast.	Steam Jet Upcast.	Downcast.	Furnace Upcast.	To Furnace Pit.	To Steam Jet Pit.		Lbs. Pr. sq. in.	Lbs. Pr. sq. in.	Cubic Feet.	Lbs.	Lbs.	Lbs.	Cubic Feet.	Feet per sec.	Inches	h. min.	Cubic Feet.
			Feet.	Feet.	Feet.			Yards.	Yards												
1852.		STEAM JETS.																			
Nov. 3.	1.	Diameter of each Pit, 7 feet 9 inches Area of ditto 47 feet Area of Air-way leading to the Upcast, 10·5 feet 67 Jets, each 0·17 inch. diameter, placed at 27 feet from Top of Pit Aggregate Area of Jets, 1.520 inches Blast-Pipe, 3 inches diameter, 7 inches area	134		151				183	5	30							17·71	0·15	1·0	11·613
„	2.	25 Jets Applied								3	25							14·0	0·10	0·30	8·872
„	3.	Furnace Applied Area, 10 feet by 3 feet 3 inches Area of Air-ways and Length of Currents, same as above						308							112		9832	29·0	0.27	1·00	18·354
Nov. 10	4.	STEAM JETS. Area of Air-way and Pits remain the same as above Boilers, 21 feet by 6 feet 67 Jets, each 0·17 inch. diameter, Steam blowing through Jets 30 minutes before measurements were taken	372		151				1827	4	31	29·56	32·4	2033	813	9·84	170	3·66		0·40	2·310
	5.	Furnace Applied Same as in No. 3 experiment as above	372	266				1777							112		6707	20·8			12·520

TEAM JET.

Date of Experiments.	Water Vaporized per hour.	Coal consumed during Experiment.	Coal consumed per hour.	Coal consumed per c. Foot of Water Vaporized.	Quantity of Air passed per pound of coal consumed.	Velocity of Air Current.	Water Gauge.	Duration of Experiment.	Cubic Feet of Air per minute passed to the Upcast.
	ubic eet.	lbs.	lbs.	lbs.	Cubic Feet.	Feet pr. sec.	Inches	h. min.	Cubic Feet.
1852. Nov. 10....	157	1680	1344	8·56	164	5.83		1·15	3·675
,, ...			112		7236	22·5			13·500
,, ...									14·600

TABLE II.

EXPERIMENTS WITH THE FURNACE AND STEAM JET.

Date of Experiments.	No of Experiments.	GENERAL REMARKS.	Depth of Pits.			Temperature of Pits.		Length of Air Currents.		Number of Boilers applied, each 21 feet by 6 feet.	Effective Pressure in Boiler, indicated by Safety Valve.	Effective Pressure on Blast Pipe, indicated by Mercurial Gauge.	Water Vaporized per hour.	Coal consumed during Experiment.	Coal consumed per hour.	Coal consumed per c. Foot of Water Vaporized.	Quantity of Air passed per pound of coal consumed.	Velocity of Air Current.	Water Gauge.	Duration of Experiment.	Cubic Feet of Air per minute passed to the Upcast.
			Downcast.	Furnace Upcast.	Steam Jet Upcast.	Downcast.	Furnace Upcast.	To Furnace Pit.	To Steam Jet Pit.												
			Feet.	Feet.	Feet.			Yards.	Yards.		lbs. Pr. sq. in.	lbs. Pr. sq. in.	Cubic Feet.	lbs.	lbs.	lbs.	Cubic Feet.	Feet pr. sec.	Inches	h. min.	Cubic Feet.
1852. Nov. 10....	6.	STEAM JETS. 67 Jets enlarged from 0·17 inches to 25 inches diameter each ..... Depth and Area of Pits the same as in former experiments	372		151				1827	5		25·05	157	1680	1344	8·56	164	5.83		1·15	3·675
„	7.	FURNACE. Depth and Area of Pits and Air-ways, same as in former experiments. Ordinary Firing	372	266		49°	110°	1777							112		7236	22·5			13·500
„	8.	FURNACE. With Quick Firing																			14·600

EXPERIMENTS WITH STEAM JETS,

AT EAST HOLYWELL COLLIERY,

11TH AND 12TH DECEMBER, 1853.

BY THOMAS JOHN TAYLOR.

The depth of the Upcast Shaft is 46 fathoms: its diameter, 9½ feet.

The usual mean temperature is 100° to 105°.

The gross quantity of air is 30,312 cubic feet per minute.

The quantity of coals consumed by the furnace averages about 40 cwt. per day, equal to 186½lb per hour, equal to 3·11lb per minute.

The duty per pound of coal per minute is therefore $(\frac{30,312}{3{\cdot}11}=)$9,746 cubic feet.

The Steam Jet apparatus made use of was applied at 8 fathoms from the surface, and contains 40 jets, each three-sixteenths of an inch in diameter, and distributed equally over the cross section of the shaft; the sectional area of each jet is ·0275 square inch; and of 40 jets 1·100 square inch: the pipes immediately supplying the jets are two inches in diameter: the main pipe is 3 inches in diameter, and is connected with a steam boiler 30 feet in length, and 5½ feet in diameter, the steam in which was kept at 36lb pressure on the square inch during the experiments.

The Jet apparatus is constructed with a side flange pipe, to admit of the application of the jets either upwards or downwards in the shaft; a main object of the experiments being to determine the result of the jet action when applied in a direction opposed to that of the furnace, and which also is the reason of the jets having been placed at only 8 fathoms from the day.

Temp. of external air from 50 to 51 deg.

On the first day's trials, the Jets were made to act in the same direction as the Furnace Ventilation. By repeated experiments, it was found that when the mean temperature of the shaft, as due to the furnace, was 95°, the Furnace and Steam Jets together produced the same result as the furnace alone at a mean temperature of 104°.

	Cubic feet per minute.
Now, the quantity of air, at a temperature of 104° from the furnace, is	30,312
And the quantity, at a temperature of 95° from the furnace, is	27,556
Difference, representing the quantity gained by the application of the Steam Jet	2,756

Thus the quantity due to the Steam Jet, under the circumstances described, was almost exactly the eleventh part of the aggregate quantity; the remaining ten-elevenths being due to the action of the furnace.

Temp. of external air 50 to 51 and a-half deg.

On the second day's experiments, the operation of the Steam Jets was reversed; being placed in direct opposition to the Furnace Ventilation, with a view to cause a recoil of the regular air current, if it should be found practicable to do so.

	Cubic feet per minute.
At the time the Jets were set on, the mean temperature of the Upcast was 104°, being the full extent to which the furnace temperature is usually carried in this shaft. The quantity of air was	30,312
The Jets were then set on in opposition to the Furnace Ventilation. Practically, the effect was scarcely perceptible, but on trial, it was found that the quantity of air was reduced to . .	27,117
Difference caused by the reaction of the Jets . .	3,195

being about one-tenth part.

The attempt to cause a reversal of the current by the operation of the Jets was persevered in by reducing the Furnace Ventilation to a very low point; so low, indeed, as a mean shaft temperature of 68°, with an air volume of only 14,434 cubic feet per minute. But when the Jets were set on with the shaft in this state, no reversal of the current ensued.

It will be observed, that only one steam boiler was used during the experiments; but that boiler consumed at the rate of 74 cwt. of coals per day, being 85 per cent. more than the underground furnace, with which its power was compared, although its performance amounted to only an eleventh of the entire duty by Furnace and Jets together. And if we consider the relative powers by which the joint effect was produced, the difference is very much greater; those powers being as the squares of the effective velocities (or, which is the same thing in this case, as the squares of the quantities of air) due to Furnace and Steam Jets respectively.

From the experiments tried, and of which a sample only has been given, it would not be difficult to deduce equations, shewing the separate results due to the Furnace, to the impulse of the Steam Jets, and to the rarified column occasioned by the latter. And such was my intention in writing this notice. On further consideration, however, I prefer waiting for that larger basis of investigation which will be furnished by the numerous other facts and experiments shortly to be laid before the Society.

LE EDEN COLLIERY,

From Experiments *eat of the Shaft only, after the Furnace had been out from five* *urs—heat of the Upcast Shaft given.*

	R PRESSURE.			CUBIC FEET OF AIR PASSING THROUGH THE MINE IN ONE MINUTE.			
	ace t.	UPCAST SHAFT.					
		At 153 Faths. just below Low Main.	At 127 Faths. just below Main Coal.	Just below Surface.	Main Coal Seam.	Low Main Seam.	Hutton Seam.	TOTAL.
1st.—With the Furnac in the Hutton fathoms from tl tant from the U made October 19 A.M., and finishe	rom ce.	125°	93°	81°	10020	9691	22959	42670
2nd.—With the Furn Steam Jet appl fathoms from th plied from three long each and 6 surface, by a 4-in Boiler to lip of Sh the area of the S 5-16ths of an inc of Jets 3·22 squ a 2-inch Pipe. the square inch October, commer ing at 5·30 P.M.	rom ce.	125°	93°	105°	11785	10956	23965	46706
3rd.—Without either only the heat made 20th Oct 3 A.M. Commen A.M., and finishe		79°	72°	69°	8357	7000	14950	30307
4th.—With the Stea made 20th Octo o'clock A.M. Com A.M., and finishe		76°	71°	102°	9872	8400	17350	35622
Comparison with Furnace alone (		125°	93°	81°	10020	9691	22959	42670
Furnace assisted		125°	93°	105°	11785	10956	23965	46706
Increase		. .	. .	. .	1765	1265	1006	4036
Comparison with Furnace alone (		125°	93°	81°	10020	9691	22959	42670
Steam Jet alone 11½ hours		76°	71°	102°	9872	8400	17350	35622
Decreas		. .	. .	. .	148	1291	5609	7048

PARTICULARS RELATIVE TO THE VENTILATION OF THE CASTLE EDEN COLLIERY,

From Experiments made by MATTHEW B. ROBSON, with the Furnace alone; with the Steam Jet and Furnace; with the Heat of the Shaft only, after the Furnace had been out from five to eight hours; and with the Steam Jet alone, the Furnace out eight-and-a-half to eleven-and-a-half hours—heat of the Upcast Shaft given.

	TEMPERATURE (FAHRENHEIT'S SCALE) AND BAROMETER PRESSURE.											CUBIC FEET OF AIR PASSING THROUGH THE MINE IN ONE MINUTE.			
	Atmosphere at top of Pit.	AIR ON ENTERING THE MINE. Main Coal at 126 fathoms.	Low Main at 152 fathoms.	Hutton Seam at 173 fathoms.	RETURN BEFORE ENTERING UPCAST SHAFT. Main Coal 126 fathoms.	Low Main 152 fathoms.	Hutton Seam 173 fathoms.	Furnace Drift.	UPCAST SHAFT. At 153 Faths. just below Low Main.	At 127 Faths. just below Main Coal.	Just below Surface.	Main Coal Seam.	Low Main Seam.	Hutton Seam.	Total.
1st.—With the Furnace alone, an 8½ feet one placed in the Hutton Seam at the depth of 173 fathoms from the surface, and 81 yards distant from the Upcast Shaft. Experiments made October 19th, commencing at 8 o'clock A.M., and finished at 12·30 P.M.	56°	59°	62°	64°	61°	62°	64½°	192°	125°	93°	81°	10020	9691	22959	42670
	29·43	30·19	30·36	30·49.	30·12	20·29	30 43	Yards from Furnace.							
2nd.—With the Furnace as above, assisted by the Steam Jet applied in the Upcast Shaft 6½ fathoms from the surface; the Steam is supplied from three High-pressure Boilers (30ft. long each and 6ft. diameter), situate on the surface, by a 4-inch Pipe (length of Pipe from Boiler to lip of Shaft 31 yards) is dispersed over the area of the Shaft by forty-two Jets, about 5-16ths of an inch diameter. Aggregate area of Jets 3·22 square inches, or equal to about a 2-inch Pipe. Boiler's pressure, 28lbs. upon the square inch. Experiments made 19th October, commencing at 1·30 P.M. and finishing at 5·30 P.M.	Temperature of the atmosphere at the top of the Pit at the commencement of these Experiments was four degrees higher than in Experiment No. 1; but there was not a corresponding increase in the Mine, it having altered very little. Barometric pressure about the same.							192°	125°	93°	105°	11785	10956	23965	46706
								Yards from Furnace.							
3rd.—Without either Furnace or Steam Jet, having only the heat of the Shaft. Experiments made 20th October. Furnace put out at 3 A.M. Commenced experiments at 8 o'clock A.M., and finished at 11 A.M.	52°	57°	61°	61°	60°	61°	63½°	95°	79°	72°	69°	8357	7000	14950	30307
	29·27	30·06	30·20	30·31											
4th.—With the Steam Jet alone. Experiments made 20th October. Furnace put out at 3 o'clock A.M. Commenced experiments at 11·30 A.M., and finished 2·30 P.M.	Temperature of the atmosphere at top of Pit, five degrees higher than in Experiment No. 3. Temperature in the Mine about one degree higher than in Experiment No. 3. Barometric pressure about the same.							91°	76°	71°	102°	9872	8400	17350	35622
Comparison with															
Furnace alone (No. 1.)								192°	125°	93°	81°	10020	9691	22959	42670
Furnace assisted by Steam Jet (No. 2)								192°	125°	93°	105°	11785	10956	23965	46706
Increase by assistance of Jet												1765	1265	1006	4036
Comparison with															
Furnace alone (No. 1)								192°	125°	93°	81°	10020	9691	22959	42670
Steam Jet alone (No. 4), Furnace out 8½ to 11½ hours								91°	76°	71°	102°	9872	8400	17350	35622
Decrease with Jet alone												148	1291	5609	7048

REMARKS RELATIVE TO THE VENTILATION OF THE CASTLE EDEN COLLIERY.

The Hutton Seam current *only* passes over the Furnace ; the air from the two Upper Seams returning into the Upcast Shaft, at the respective Ingates, without passing over the Furnace This accounts for the greater increase in the Main Coal and Low Main Seams by the assistance of the Jet ; and for the greater decrease in the Hutton Seam than in the other two Seams, when the Furnace was out, and the Steam Jet only applied.

Area of Downcast Shaft, after deducting spaces occupied by Pumps, Buntons, Slides, &c. - - - - - - sup. feet.

Area of Upcast Shaft - - - - - 58·5 „

Temperature at face of workings in the Main Coal Seam, 60 deg. when the temperature at the Intake was 59 deg., and the return 61 deg. Fahrenheit.

Temperature at face of working in Low Main Seam, after passing through Stables, 64 deg. when the temperature at the Intake was 62 deg., and the return 62 deg. Fahrenheit.

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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING ON FRIDAY, MARCH 4, 1853.

DURHAM:
PRINTED AT THE CHRONICLE OFFICE, 67, SADDLER STREET.

1853.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING, HELD IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, FRIDAY, MARCH 4, 1853.

NICHOLAS WOOD, ESQ., PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meetings having been read,

Messrs John H. Forster, Robert Nicholson, Martin Seymour, and Wm. Hawthorn were elected Members of the Society.

The PRESIDENT said he believed this was the day set aside for the discussion on the comparative merits of the Furnace and the Steam Jet in the ventilation of collieries. He was sorry to say the printing of the papers relating to the experiments which had been made upon the subject had occupied much longer time than he had any idea of, and he believed, therefore, that the experiments made by himself were in the hands of only a few members at the present moment. The delay had been caused by the great length to which the experiments extended, the number of plates to be prepared, and the tables introduced; he believed the printers had done all they could—they had been working for the last month, but only a few copies were yet out of their hands. He had also received a letter from Mr Elliott, who, they would recollect, had been making a great many experiments, which he said he would lay before this meeting. That gentleman was in London, and could not attend on the present occasion. (The President having read Mr Elliott's letter, proceeded.) Under these circumstances, he thought it quite impossible they could take the discussion that day with any of sort of advantage; on the contrary, he thought it would be much better to defer the discussion for another month, when gentlemen would have an opportunity of reading over and carefully digesting the contents of the several papers, and would come prepared to discuss the question. He considered one meeting should be entirely set aside for the purpose of such discussion, in order that they might endeavour, if possible, to set this important matter completely at rest. There had been some other papers put into his hand for reading, which would be now read. Mr

Dunn had also made application to read to this meeting some experiments which had been made by himself and the other Government Inspectors at Seaton Delaval; but, as these experiments had been published, they could not be incorporated in the proceedings of the Institute. The Council, however, saw no objections to their being read.

Mr Dunn then read a "Report on the Ventilation of Mines, with reference to the Steam Jet and Furnaces at Seaton Delaval Colliery," prepared by himself and the other Inspectors of Coal Mines.

The President.—With reference to the quantity of air due to each pound of coal, it may be necessary to state that four boilers were used, and 33 jets of three-sixteenths of an inch in diameter; now, 33 jets could not by any means pass the steam raised by the four boilers. Therefore, the quantity of fuel used by the four boilers would hardly be an accurate measure of the quantity of air due to each pound of coal when used as a steam jet, as all the steam did not pass through the jets. In one of his experiments with two boilers and 40 pounds to the inch pressure, 61 jets, three-sixteenths of an inch in diameter, were required to pass all the steam generated by those two boilers.

Mr Longridge.—Was the pressure of the Steam Jets ascertained in Mr Dunn's experiments as well as that upon the boilers?

Mr Dunn.—The pressure on the boilers was about 35 lbs. to the inch.

Mr Longridge.—Then you might have had a very different pressure at the jets. There must have been a throttle valve between the boilers and jets.

Mr Dunn.—Yes.

Mr Longridge.—Then the pressure at the jets would depend upon the opening through that valve. With 35 lbs. pressure upon the boilers there might not be more than 5 lbs. pressure passing through the jets. It is, therefore, very necessary, in such experiments, to ascertain the pressure of steam through the jets.

Mr Dunn.—We had no opportunity of doing that. The experiments were made with a working engine, and, therefore, the pressure upon the jets would be varying continually during the day.

The President.—The probability is, the whole pressure of the steam would exist at the jets, because, the jets being incapable of passing all the steam, there would be no necessity to throttle the steam between the jets and the boilers.

Mr Longridge.—I asked the question whether the whole of the steam generated by the boilers went through the jets. I understand a portion

of it went to the engines. When you take 60 horse-power from the boiler to the engines, the rest of it passing through the jets would not, in my opinion, issue from the jets at anything like 35 lbs pressure.

The PRESIDENT.—Was the engine working during the time you were making the experiments?

Mr DUNN.—Yes; occasionally.

Mr LONGRIDGE.—And all the exhausted steam was passing to the upcast also?

Mr DUNN.—Yes; of course.

Mr LONGRIDGE.—And the heat of it would add to the effect of the shaft?

Mr DUNN.—I was prepared to state what I consider a very important point with regard to the upcast pit, and which I almost determined to put upon paper as a resolution. The area of the pit is 50 feet. The quantity of air absorbed by the boilers I consider equal to one-fourth, or 12 feet area of the shaft. Mr Forster's calculations and my own make it about one-quarter of the total; therefore, say 12 feet. The increased temperature was very little short of 100 degrees; and, consequently, if the steam and boiler increased the bulk in the admitted proportion, it would occupy other 10 feet; that would be 22 feet taken from the pit of 50 feet area. It would only leave a clear passage from the mine of 28 feet, which would, of course, vary with the state of the boiler fires. One important question to determine is, how far an increase in the number of boilers affects the volume of air passing through the mine. It would appear that the multiplication of boilers did not increase the volume of air in the colliery; because, when Mr Forster gave his evidence before the Parliamentary Committee, there were only two boilers in use at Seaton Delaval; and, if four boilers were now employed, most practical men would say there ought to be a corresponding increase of air, making allowance for the extension of the air courses, which was not found to be the case. I would, therefore, suggest how desirable it would be if, either at the instance of this Institute or any other way, a new, independent, select committee of practical men were appointed; so many nominated by Mr Forster, and an equal number by Mr Wood, to re-investigate the figures and results, seeing that such great discrepancies exist between them; such committee to go into all the minutiæ alluded to by Mr Longridge. I merely throw the suggestion out, so that the meeting can act upon it if it thinks proper.

Mr HALL.—I believe Mr Forster differs from Mr Dunn and his colleagues with respect to the quantity of air going through the mine.

Mr Dunn.—That strengthens my suggestion. If Mr Forster is sensible that he is right, and we are sensible that we are right, it only shows how desirable it is that the matter should be re-investigated by an independent committee, made up conjointly by the two parties.

The President.—I suggested that it would be better that the whole of the papers which have been prepared upon the subject should be read, and laid before the Institute before going into a formal discussion. They have now been printed, so that gentlemen may read and consider them; and it is quite competent for Mr Forster, and the other advocates of the Steam Jet, to make further experiments, either to corroborate or contradict those which have already been made. I think it would be better, also, to take this month to look over those experiments. They are very voluminous, and very important; and then we shall come prepared to discuss them at the next meeting. It is probable by that time we shall hear something on the subject from Mr Forster, Mr Gurney, or Mr Darlington. With reference to Mr Dunn's observations about the size of the shaft, and the obstruction therein of the air, you will find that the largest quantity of air that passed out at Seaton Delaval was 50,660 cubic feet per minute; passing through the upcast at a temperature of 130°, measured 30 yards from the top. The medium temperature would be more: that was through 50 feet area. Supposing the temperature was increased to 150°; in that case the expansion would be little more than one-fifth, which would make it about 60,000 cubic feet. Now, that is only about 1,200 feet per minute for each foot area of shaft, which is no great velocity to obtain in an upcast shaft. At Tyne Main, the shaft is exactly the same area, and there we had a working quantity of nearly 100,000 cubic feet per minute, which is upwards of 1,800 feet per minute for each foot area of shaft: therefore, there appears to be nothing in the size of the shaft that would affect the experiments. I think the experiments would be affected by the degree of pressure at which the steam issued from the jets; but with four boilers at work, the probability is that the pressure would be the same, or nearly so, as in the boilers.

Mr Dunn.—By the bye, when we made the experiments, the whole of the steam was used.

Mr Taylor.—That question was asked.

The President.—You do not state that in your paper?

Mr Dunn.—But that is the fact.

Mr Longridge.—The temperature is taken in the upcast shaft?

Mr Dunn.—Yes.

Mr Longridge.—Then I would observe that there should be an allowance made for the great quantity of aqueous vapour held in suspense in the shaft, making at least two-thirds more than the quantity of air.

Mr Dunn.—The quantity of air passing would be diminished still more in that view.

Mr Longridge.—Yes; the quantity of air would be diminished considerably. I have made some calculations upon it. I find the quantity of aqueous vapour contained in a cubic foot of air, of 152° in temperature, to be 0·013 lbs. in weight, and its volume 1·666 cubic feet. If that amount of aqueous vapour be combined with every cubic foot of air, the actual bulk will be 2·666 cubic feet, causing an increased resistance to be overcome in the shaft.

Mr Greenwell.—Would not the same circumstances exist without the jets?

Mr Longridge.—No; in that case it is a saturation, but without increasing the bulk.

Mr Greenwell (to Mr Dunn).—Did you measure the air in the mine immediately after you measured the air in the upcast shaft?

Mr Dunn.—Yes; there is no great discrepancy on those points. We measured the air by means of powder smoke and found 26,800 cubic feet of air going into the north workings, which was close upon that reported by Mr Taylor in 1849; this was from the boilers, and was considered a good proportionate ventilation for the mine. We obtained 26,800 cubic feet; Mr Taylor's result was 26,473 feet. With the Steam Jets in operation, the amount of air going in was increased to 38,000, as it stands in the colliery books.

Mr Longridge.—Did the colliery people assist you in the measurements?

Mr Dunn.—Yes; the air was measured by means of powder smoke, and also with the anemometer in that case. We had anemometers in other experiments.

The President.—Out of 50 feet area of the shaft, you calculate that 12 feet is occupied by smoke and steam which does not go through the mine at all. You then put down other 10 feet for increased bulk, caused by expansion; making 22 feet taken from the 50 feet shaft, leaving only 28 feet for the ventilation of so large a mine.

Mr Longridge.—You must apply exactly the same reasoning to the furnace, for you may just as well say a certain portion of the shaft must be taken up by the supply of air to the furnace.

Mr Dunn.—No, it is quite different; if you bring the return air to the fires, the more intense the fire the greater the air.

Mr Longridge.—But that element must enter into any calculation of comparative merit as between the furnace and the Steam Jet. For, supposing such difference to exist, by bringing the return air over the furnace there would be no such reduction from it; it is the air of the mine.

Mr Dunn.—But there is a necessity for taking the boiler split from the fresh air to the boilers.

Mr Longridge.—Yes; because they cannot work them otherwise.

The President.—The question is, whether or not the shaft is too small for the air to pass up it. The area of the shaft is 50 feet. The quantity of air we have in the workings is 46,466 feet; and suppose there be an increase by the jet of one-sixth, that would be 54,000 feet in a 50 feet shaft. Now that is about 1,100 cubic feet per minute for every foot of the shaft. You will find that to be a very low average in the trade. You will find 2,000 feet to be more common than 1,000 feet. If you look at the diagram of the Tyne Main ventilation, you will find the resistance in the shaft at 1,000 feet per minute is very small; but when the velocity amounts to 3,000 feet per minute for each foot of area of the shaft, then you find the resistance to be very great.

Mr Dunn.—But how does it happen that with four boilers at work there is only this quantity of air? I do not think, in speaking about a fifty feet area of shaft, you are making due allowance for the space occupied by the smoke. Is there not something material in there being a large quantity of smoke not completely consumed?

Mr Longridge.—No doubt every portion of black smoke is so much carbon to be carried out, and, therefore, mechanical power must be used to carry it out.

Mr Dunn.—Then it would have to be driven away by the furnace?

Mr Longridge.—Not if we consumed it, as is done by the furnace. If you can consume it by the furnace, you may consume it with the boiler. It is the great secret of consuming smoke to give plenty of air. With the furnace the carbon, instead of being carried out, falls back upon the fire and is burnt.

The President.—There is no doubt the coals used in an engine fire produce more dense smoke than is produced by the furnace.

The President then proceeded to read a letter received from the Marquis of Londonderry, enclosing a communication received by his Lordship from Mr Eikes, who proposed to introduce a plan of exploding the carburretted hydrogen in coal mines, by means of electricity daily, so as to prevent its accumulation to such an extent as to be dangerous. The President stated that the communication had been laid before the Council, who had

directed him to ask some questions of Mr Eikes relating to the practical difficulties attending the ventilation of mines, and the manner in which he proposed to overcome them. He had done so, and that gentleman had replied. The whole of the correspondence having been read, a short discussion followed, in the course of which Mr READ, of Pelton, said he should be very glad to afford Mr Eikes an opportunity of trying his experiments in a colliery under his care; and the President was authorized to inform Mr Eikes thereof, intimating that every necessary apparatus would be provided on the colliery.

The desirability of increasing the funds and extending the benefits of the Institute having been brought under the consideration of the meeting by the President, it was, after some discussion, resolved that the various coal-owners and others interested in the trade should be applied to for contributions, offering to subscribers the privilege of sending a certain number of persons, such as overmen, underviewers, and intelligent workmen to the meetings of the Institute, so as to enable them to avail themselves of the information conveyed by the papers that were read, and the discussions that arose from time to time.

The PRESIDENT then said he believed there was but one other subject to come before the meeting that day; which was a new mode of changing the clacks in a pumping engine. It was a very ingenious plan. Mr Thomas John Taylor would explain it.

Mr TAYLOR exhibited a neat working model, to illustrate the invention; and read the following written description sent by the inventor, who lives near Kelso:—

Old Dryburn Lime Works, 11th December, 1852.

SIR,—The object of the model pump which I sent you, is that either of the clacks may be changed, without any interruption in pumping, by shifting the two sliding valves from the one pump to the other: or it is done by two screws—one at the top and the other at the bottom of the clack door. The other four smaller flat-headed screws are for keeping on the doors. The joint in the middle of the pump does not screw fully up; but it goes as far as making it air tight.

THOMAS WEBSTER.

Addressed to
Richard Douglass, Esq., Bunker Coldstream.

The meeting then adjourned.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING

ON FRIDAY, APRIL 1ST, 1853.

Newcastle-upon-Tyne:
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1853.

NORTHERN INSTITUTE

OF

MINING ENGINEERS.

MONTHLY MEETING, FRIDAY, APRIL 1, 1853, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE,

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

THE minutes of the Council having been read,

Mr. Robert Stephenson, M.P., was elected a member of the Institute.

The PRESIDENT stated that this meeting was specially set apart for the discussion of the Steam Jet, in the hopes that Mr. Gurney or some of the promoters of that system of Ventilation would be present. Previously, however, to entering upon the discussion, he had a subject of great importance to this district, and to the mining and manufacturing interests especially, to bring before them.

They were quite aware that the subject of the establishment of a School or College of Mines and Science had for some time engaged the attention of the mining, and manufacturing interests of this district. An obstacle to the establishment of this institution had hitherto presented itself in the existence of two medical schools in this town; or rather a medical school in connection with the University of Durham, and a school or college of science and medicine. As there could be only one attached to an institution of this kind, the existence of two, each having probably equal claims upon the Government for consideration, presented an obstacle in the outset. He was, however, happy to say that there now existed great hopes that a reconciliation would take place between them, and that they would present themselves as a united body in the promotion of so desirable an object.

The members of the Institute would recollect that a committee had been appointed in furtherance of this object, and for the promotion of

the establishment of the institution to which he had alluded; and he had the pleasing duty to report to them, that considerable progress had been made in discussing the plans, and in arranging the general outline of the scheme.

As President of the institution, he had put himself in communication with Dr. Lyon Playfair, and the Warden of the University of Durham, and a Committee had been formed of gentlemen representing the Corporation of Newcastle, the Coal Trade Interests, the Mining Institute, the Lead Mining Interests, and the Manufacturing Interests of the district;—for the purpose of ascertaining and considering the system of scholastic or collegiate industrial education best suited to the wants of the district, and for that purpose to confer with the Government Institution, and with the University of Durham, and to report their labours to a meeting hereafter to be called.

Having given the subject great consideration, and having gone fully into the matter with Dr. Playfair, and the Warden of the University, and with other gentlemen conversant with such subjects; the President said, he trusted he might give them an outline of what appeared the requisites of this district, so that they might consider the same, and at a future meeting be prepared to discuss the subject, and to come to some determination thereon.

It was thought that the system of collegiate instruction, which was of course intended to be of a purely practical or industrial character, might be complete for *First Class Students* by a course of three years' study, viz.:—

1st Year—Geology, Chemistry, Arithmetic, Algebra, Geometry, and Geometrical Drawing.

2nd Year—Practical Chemistry, Physics, Mechanical Science, Higher Mathematics, and Drawing.

3rd Year—Mining, Machine Drawing, Principles of Machinery, Analytical Chemistry, Geological Surveying, and General Surveying.

And that this would require an establishment of four Professors or Teachers, viz.:—

Professor or Teacher of Arithmetic, Algebra, and Geometry.

———————— Geology, Geological Surveying and Mining.

———————— Chemistry and Physics.

———————— Principles of Machinery, and Machine Plan and Drawing.

It was, however, suggested, in addition to these, that a system of in-

struction or a special class might be adopted; by which, for instance, pupils intended for under viewers or manufacturing superintendents might be instructed in twelve months. Three years would probably be too long a period for them to attend, and besides, such persons would scarcely require all the instruction that would be given to a pupil of three years. It had been therefore thought that a class might be formed in which instruction should be given to this class of persons, sufficient for their purpose, in twelve months, and at a cheaper rate; and that the course of instruction of this class might consist of instruction in General Chemistry, Physics, Geology, and Mining, and in Plan Drawing.

Besides these classes, it had been suggested that an evening class for artisans, and others whose daily occupation preclude them from attendance during the day, might be extremely useful, by which they might obtain useful instruction on moderate terms.

There was, however, one important subject connected with such an institution, viz.:—that of the preparatory education of pupils intended for such a course of instruction; as unless the whole course of study harmonised, it would not be complete or successful.

It would appear that boys coming from the ordinary schools would not be quite fitted to enter into the College, or would enter disadvantageously—and it had been thought that either within the College, (as in King's College) a school should be established; or, that connected with the College, but with the course of education adapted to the College tuition, district schools might be established to prepare pupils for the Institution by giving them a course of education more particularly adapted to industrial science and art. This might be accomplished by arrangements with existing schools.

The manner in which the details should be carried out would depend upon the patronage which such an Institution met with, and the amount of funds subscribed at the outset, by the manufacturing, commercial, and mining interests of the district.

Government, it was understood, was disposed to aid in supporting such Institutions, or, at any rate, in supporting them to such an extent as that they may be properly established; and it was also hoped that they would give assistance to the district schools, as naturally promoting the welfare of the College. With respect to the College itself, the Government would, it was understood, guarantee the possessors a certain amount of salary for, say five years, (considering five years a sufficient time to test the practicability of establishing such an institution, for unlesss the Institution supported itself in five years, the presumption was, that there was no ne-

cessity for it, and that the district was not capable of supporting such an Institution, in which case, the sooner it was abandoned the better. In such guarantee of the salaries of the professors for five years, the Government would of course have the fees, whatever they amounted to. If the fees amounted to more than the guarantee, the Government would, of course, pay nothing, but if they did not, they would pay the difference, It was intended that this Institution should be in connection with the Government College of Science and Art in London, and that meritorious pupils should be taken into that institution on the most favourable terms, probably to the extent of providing for the maintenance and education of a certain number, (in proportion to the number of pupils in the local College); and of the education of others at a very moderate cost, such pupils having undergone certain examinations in the local College, previous to martriculating in the Central College in London. Rewards, exhibitions, or certificates of merit, to pupils of superior attainments or industry, would also be given as a stimilus to exertion. The Government Institution would also give models and drawings of machinery apparatus, &c., at very moderate rates, and these, it will be observed, would be a great advantage to the local institutions, and to the mining interest generally of this district; inasmuch as the Central Institution being connected with similar institutions on the Continent and elsewhere, they would receive models and drawings from thence, which would be transmitted to the district Institutions throughout the country. This was a sort of outline of what they would have to consider with regard to the establishment of this College. There was another consideration which had been discussed amongst the parties who are promoting this scheme; which is, the propriety of a connexion with the University of Durham. It had been considered by parties with whom he had communicated, that a connection with the University of Durham would be a very great advantage and assistance to this Institution. They would observe from what was stated that the course of scientific education would be complete as between the establishment here, and the central Institution in London, without any connection with the University of Durham; but he thought, and many other gentlemen thought with him, that a moral and religious character would be given to it, a security for the morals of the pupils, if it were in connection with the University, and that such connection would be highly advantageous likewise in a scientific point of view (*hear, hear*). He had been in communication with the Warden of the University of Durham, upon the subject, and he was happy to inform them that, in his opinion, it was perfectly possible that a connec-

tion might be established with that University, by which they should obtain all the advantages that would result from it, both in a moral and scientific point of view, and that this might be done without interference with the religious feelings of any sect, on the part of the University. He thought the manner in which the Warden had met this subject did infinite credit to him (*hear, hear*). He says, "We have no feeling with respect to such an Institution, except that of strengthening it, and doing it good; we do not wish to exercise controul over the local management; we do not wish to assume the responsibility of management, or interfere in any way with the direction of its affairs; but if we can be of use to you, we shall be very happy" (*applause.*) He might state that the Institution would probably be managed by a general council representing the different interests of the district; mining, manufacturing, and commercial, and they would determine the course of science and learning that would be taught in the College. All responsibility of management would, of course, rest with the council, and the Warden of the University did not wish, in any way, to interfere with such management. He believed by means of a connection with the University, they should obtain very great advantages, and also probably some pecuniary benefit. He believed the pupils of this Institution might be admitted to honors in the University of Durham up to a certain extent, without reference to their religious principles *(applause).* He believed it was quite competent for them to be admitted up to the degree of Bachelor of Arts, without being questioned upon their religious principles *(hear, hear).* His own feelings, therefore was, that it would be highly advantageous to be in connection with the University of Durham. There was another point which has also been thought deserving of great attention, and that was, whether some arrangement might not be made with the Literary and Philosophical Society of this town, as well as with the Natural History Society. The Literary Society possessed a very extensive and valuable library, which would be very useful to the pupils; and, as that Society had been established for the promotion of learning, it would, no doubt, be glad to render assistance for the promotion of such an object as this. Such a connection would also be of advantage to the Society, because the books obtained by the College might go into the library of the Society; and some general arrangements might be made for the use of them. The probability was, too, that the rooms of each Institution, might be made useful to both concerns. Such an arrangement had been suggested by parties of considerable influence in the Literary and Philosophical Society, and he thought it might be conducive of great good Then with respect to the Natural History Society, that Institution had a very good

museum, but, like all museums, its utility was very much diminished by not being brought into practical use *(hear, hear)*. Such specimens might be extremely useful in the education of the pupils, and could be so made use of in this College ; and in the same manner as he had referred to, in respect of the Literary and Philosophical Society, the models of machinery, specimens of manufacture, and other objects of that description, collected by the College, would be deposited in the museum of the Natural History Society, and both parties would gain much by such an arrangement. In conclusion, he was very sanguine in his hopes, that if this Institution could be established, it would be productive of immense advantages to the district; and he might take the liberty of saying that there was not probably any district in the country, where such an Institution was so much required, or where the chances of success was so great; and allow him to add, where the patronage of Government would be more usefully bestowed. He would therefore ask them to consider the matter over, and as it had been deemed advisable that a memorial should be got up by this Institute, pointing out the necessity for such an Institution, and praying for all the assistance that the Government can give it; if they thought proper to appoint a committee to draw out such a memorial, he should be very happy to render it all the assistance in his power (*applause.*)

Robt. Stephenson, Esq., M.P., said—Although a young member of this Institution I am tempted on the present occasion to make one or two remarks, in the first place confirming the view of the President with respect to the intentions of the Royal Commissioners, one of whom I have the honour to be; but, as some misunderstanding has gone abroad with respect to the tone of the report issued by them on the subject of making the surplus fund available for education, I am anxious to remove from the mind of any one here that misunderstanding. The tone of the report perhaps has rather led to the view of Government centralization in London—that the Institution in London should have more influence than was really intended over the branches or colleges that may be hereafter scattered through the country. The conclusion might be justifiable, but it is not the intention of the Commissioners to exercise any controul over the local management of such institutions. Though not openly advocated, such interference, it is alleged, might still exist to a certain degree, and wherever Government aid is called in it ought to be received with the greatest caution. If that aid be important and extensive in a monetary point of view it is sure to become in the end an incubus on the local College ; therefore, I advise you, by all means, in considering this

question over, to throw over-board entirely any consideration of Government aid. Accept that aid which they can give you—I believe it will be most liberal—but do not let that aid, whether great or small, interfere with, or enter into, any calculation of the basis of such an Institution. Let the Institution be an institution founded upon and adapted to the wants of the neighbourhood, like the University of Durham—let it be an Institution connected with the Coal Trade, and call upon the members of the Coal Trade for support, and only take the Government aid to secure additional advantages, for unless such institutions support themselves, I am sure no Government aid will ever maintain them *(applause)*. I will also direct your attention to the example of the Cornish Mining School, which has been successfully established in Cornwall for a great number of years. Its rules and regulations have for the most sprung out of experience, or have been suggested by the necessities of the case. I would advise this Institution, before forming itself into a compact body, to consult the authorities connected with the Cornish Institution, who are men of high scientific attainments, and have been eminently successful in bringing the principles of science to bear upon the practical working of the mine. The object of all such institutions should be to make practical men scientific to a certain extent. I do not mean that overmen and underviewers should be exclusively scientific men, but they should be made conversant with the abstract principles of science, which they can with practical knowledge bring to bear, and they cannot be brought to bear without saving many human lives in a country like this. I think it the right end to begin at—to attempt to make practical men scientific rather than as Government sometimes attempts to make scientific men practical *(applause)*. To make an abstract scientific man practical, you will say, perhaps, is easy enough. No such thing. The principles of science are simple, but the art of practice is exceedingly difficult—you must labour to attain it; for it is only by actual abour that even the highest scientific attainments can be brought to bear successfully in practice. In corroboration of this statement, I may refer to a report which was made to Government some years ago, by the Inspectors appointed to examine into the working of Mines. That report was drawn up by perhaps one of the greatest genius of which this country or even continental nations can boast, and in that report upon Accidents in Coal Mines he made some suggestions for the adoption of remedial measures. Now, no practical man in this district can have read that report without feeling that, with the highest scientific attainments as displayed in the course of that investigation, there was absolute ignorance with respect to the ma-

nagement of a pit and the practice of working the mine *(hear, hear)*. When I mention the name of Faraday, it will at once prove what I assert—for it is a name which has raised this country to a level with any other in Europe, and is associated with a reputation that will render that name immortal (*applause*). But this is a case illustrative of the point to which I wish particularly to direct your attention—that report is decisive—and I would earnestly recommend that it should be read over by every member of this Institute; and, if he is a practical man, however high his respect may be for Mr. Faraday and his coadjutors in this case, he will be convinced that his suggestions have no real existence *(hear, hear)*—that they were purely theoretic. Now, that is what I mean by saying that it is more difficult to make a scientific man, however high his attainments, practical, than to make a practical man scientific, so as he may bring the principles of science to bear upon the Ventilation of Coal Mines. I have introduced these observations with a view to urge you not to depend too much upon the Government, but to depend upon your own resources. In the commencement you may meet with difficulties, but with perseverance you will overcome them, and may, no doubt, rank upon the same level with the Mining Society in Cornwall, which has done a great deal to awaken an interest in and promote the success of mining in that district. In the county of Durham, and the adjoining county of Northumberland, such an establishment is even more required than in Cornwall, which is more interesting, perhaps, in a geological point of view; and where the miners have not to contend with those difficulties connected with Ventilation which are met with here, and in encountering which you have to depend upon scientific principles to so great an extent. There is also the great question of humanity involved which you must not forget. In many cases accidents and loss of life occur entirely through the ignorance of the practical miner. This was remarkably illustrated in the calamitous accident that occurred at Wigan the other day, where, as we read in the evidence at the inquest, one of the sliding frames in the upcast pit got deranged, and a tub stuck fast, so that they could not send the carpenters down to repair it on account of the high temperature. The under viewer caused the furnace to be damped. If he had had the least notion of the effect of damping the furnace he would have seen that by doing so he jeapordized the lives of all the workmen in the mine. The temperature was reduced, the air in the pit became stagnant, and an explosion was the result. The accident has been ascribed to a trap-door. The pit had been visited by two Inspectors, the Ventilation was generally good, and the mode of working

the mine judicious; but in this instance the under viewer was ignorant of the effect of damping the furnace, or had overlooked it. If it had been impressed upon his mind as a scientific fact he could not have forgotten it *(hear, hear)*. It is the object of this School to raise up young men with sufficient science, and to impart to practical men sufficient science, to meet a case of this kind *(applause)*. If this overman at Wigan had been acquainted with the principles of Ventilation, as he ought to have been, and as I hope all charged with the management of mines will be in this neighbourhood under the operation of the proposed schools, the lives of fifty human beings would have been saved. It is the great cause of humanity in which you are engaged, and if prosecuted with vigour and energy, I am sure your exertions will be crowned with success *(applause)*.

The PRESIDENT recommended a perusal of the second report of the Commissioners on the Exhibition of 1851, which contained a great deal of matter relative to the establishment of such institutions as the one now proposed; and also of a lecture by Dr. Playfair, in which he gives a full account of the Industrial Institutions of the Continent. He expressed his entire concurrence in the observations of Mr. Stephenson.

Mr. STEPHENSON moved that the Vice Presidents, together with the President, form a Committee for the purpose of drawing up a memorial to the Board of Trade on the subject of the proposed schools.

Mr. REID seconded the motion, which was put and carried unanimously.

The PRESIDENT, said—They would now proceed with what had been the intention of this meeting, namely the discussion relative to the respective merits of the Furnace and the Steam Jet, in the ventilation of coal mines. He should be happy to hear the opinions of any gentleman upon the subject.

Mr. MATTHIAS DUNN, said—He believed all the members present were so far agreed upon the point that there was really no element of discussion between them. The experiments of the President and other gentlemen had been so conclusive as to the superiority of the Furnace over the Steam Jet, that he believed no gentleman would be found to come forward in defence of the latter. It was decidedly his own opinion that the Furnace was superior to the Jet both in point of effect and economy.

Mr. STEPHENSON, said—Sir, I have had great pleasure in reading, in a very general way, the valuable report of experiments made by yourself, on this interesting subject—interesting because I think a doubt has hung

over men's minds respecting the relative efficiency of the Steam-blast and the Furnace, which has led to the adoption of the former in cases where there might have been, and which I believe do involve, real danger; and, therefore, the whole mining world, especially the coal mining districts are deeply indebted to you for your valuable and faithful experiments, which you have placed on record, and which leaves now, in minds who dispassionately consider those experiments, no doubt whatever (*applause*). I remember that previous to your making those experiments I had the pleasure of discussing the form of some of them with you, and you then expressed, as both of us expressed, our apprehension, that the Steam Jet, on principle, could not by any possibility succeed, for you thought it was a misapplication of force to attempt by a Steam Jet to raise a column of air by its mechanical impulse; and you thought the error had arisen from a mistaken view of the cause of the efficiency of the Steam Blast in locomotive engines, which has created, there can be no doubt, an absolute revolution in society (*applause*). It has enabled the locomotive engine to assume a character, a new position, which it never could have done without it; but to apply that same force to entirely different circumstances, is an abuse of principle, and it deserves to be characterized by no other name (*applause*). Besides the efficiency of the locomotive engine blast, forcible and violent as it is, is by no means very great as to the quantity of air it moves. It draws a very small quantity of air through the fire, as compared with the quantity of air which we want to have drawn through a mine. And it also involves this principle, that locomotive engine builders have found, that if you apply the Steam Jet in a large chimney it is of no use whatever; it requires that the chimnies should be so constructed that the Steam Jet absolutely fills it in a very energetic state. If you widen the chimney and raise it one hundred feet high, the whole mechanical force of the Jet will be expended on the elasticity of the air in a very few feet; and whether you apply it at the top or the bottom the result is the same, for you apply it to an elastic spring. If you take the Steam Jet to the bottom of a pit shaft what do you do? you press an elastic spring, and the spring absorbs all the power of the Jet; so that its effect is entirely arrested. The further you have gone in your experiments with the Jet and the Furnace the more decisive has been the result. The disparity between them is so immense, that I trust I shall never more hear of the Steam Blast being used as the means of ventilating an extensive colliery (*applause*). I am quite sure if that system be persevered in, it must lead to very lamentable consequences (*hear, hear*). In some mines even with the Furnace the air becomes more

inflammable than in others, but there are expedients within the collier's reach by which danger may be averted; and even when the Furnaces become dangerous, with those expedients at hand. they are infinitely more valuable than the Steam Jet. Indeed the mechanical force of the Steam Jet whenever it is applied, is confined to a very narrow power. I have seen the system generally applied at the Polytechnic Institution in London, where it makes a great noise, and draws in a large quantity of air in a Lecture Room, but the force required to do that bears no comparison to the enormous amount of force required to draw the air through the workings of a mine. I quite agree with Mr. Dunn that there is very little left for any of us to say. You have completely exhausted the subject, and to my mind in a most satisfactory manner.

Mr. Boyd—The experiments which have been instituted prove that the Steam Jet, even as an assistant power, is very little effective, and after the first few moments of its being in action, after a column of air has been put in motion by the use of the Furnace, its influence is positively unappreciable. You only receive a certain small increase of ventilating power by the Steam Jet, and that power seems stationary at that point, and has no more power over the column of air. A substitute for the Furnace has as yet to be discovered.

Mr. Stephenson—We may have to seek hereafter for some substitute for the Furnace under particular circumstances, but the Steam Jet does not promise much in that direction. If we are to have the application of steam, I am prepared to prove that its application to pump air would be much more effective in Ventilation than the Jet. I contend that the Steam Blast is one of the worst modes of applying the mechanical power of steam to the ventilating of coal mines.

The President—One object I had in view in the experiments I made was, to ascertain whether the Steam Jet was useful as an auxiliary or not, because up to the point at which the Furnace and the Steam Jet act together, or are of equal power, the Furnace is unquestionably the most effective and economical of the two. The question is, whether after that the Jet is an auxiliary to the Furnace or not, and if so, to what extent it is useful or beneficial. I made all the experiments I thought likely to bring that result out. I ascertained, as might have been expected, that when the Jet was applied to a current of air moving at a very great velocity, its application as a mechanical power becomes proportionately less, and when the velocity gets up to the extreme limit of the Furnace, the Steam Jet is scarcely able to follow the air. I found it rather opposed it on the whole, and that the air had to drag the steam after it, and con-

sequently I found a deficiency of effect. If you read the experiments at Killingworth, and the tables of rarefaction, at different temperatures and velocities, you will see this effect illustrated. There can be no doubt that an efficient auxiliary to the Furnace is exceedingly desirable in a mining point of view in certain cases. With reference to that point there is now erecting in South Wales, by Mr. Struve, a very powerful machine, which I had an opportunity of making some inquiry about when in that neighbourhood the other day. The piston is about 20 feet in diameter, and it is calculated to pump out about 10,000 cubic feet of air in each stroke. I quite agree with Mr. Stephenson that steam employed in working such a machine is likely to be much more effective than when blown out of a Steam Jet. I am strongly of opinion that this machine will be extremely useful, although the Committee of last Session came to the conclusion, that no mechanical power could be practically useful in ventilating mines. With reference to the risk of passing air through the Furnace in an inflammable state, I need not mention that it is not necessary that the whole current of air should go over the Furnace. The ventilating power of the Furnace is not necessarily connected with the air passing over it, but on the quantity of heat in the shaft. In the experiments at Hetton there was a portion of air that did not go over the Furnaces. There were two seams ventilated by about 60,000 cubic feet of air per minute which did not pass over the Furnaces. The Furnace may be used in the same way as the boilers of the Steam Jet is now used, with a current of air going direct from the down-cast to feed them. If you can burn sufficient coal, so as to produce the requisite heat in the shaft, you obtain the same result whether the air pass over the Furnace or not. That is well known to every gentleman in the profession. We find, however, there is a great deal yet to be done with regard to Furnace Ventilation. I think the subject by no means exhausted. A great many matters suggested themselves in the course of these experiments of which we were only partially acquainted at the time, and I intend at some future period to prosecute the inquiry further. The subject, as I said, is by no means exhausted, and I hope the members of this Institute will not come to the conclusion that it is so. A great deal yet requires elucidation, and I hope in the course of time we shall receive from the various members exceedingly valuable papers on the Ventilation of Mines. It is a momentous subject;—the most lamentable accidents occasionally happen;—and it is incumbent on the members of this Institute to do everything in their power to avert those dreadful occurrences.

Mr. Reid—With respect to the observations of Mr. Stephenson, the

question seems to be can, steam be in any way or mode available for the Ventilation of Mines. Here is a paper, read some time ago before the Academy of Sciences at Brussells, by the Chief Engineer of the Belgian Government, developing an application of steam by conveying it down the shaft. It was published in 1836.

Mr. STEPHENSON—I saw it very shortly after it was published, and no doubt it is a better application of steam than the Jet.

Mr. M. DUNN—Since we are honoured by the company of Mr. Stephenson, I would take the opportunity of adverting briefly to the circumstances of Seaton Delaval Colliery. The Committee of the House of Commons were told of the extraordinary effect produced in that colliery by the use of the Steam Jet, and I would like to explain to Mr. Stephenson the actual circumstances under which that effect was said to be obtained. There are six shafts, each fifty feet in area, used in working the colliery—four being down-casts in area 200 feet—the fifth is an up-cast of 50 feet—and the sixth a dormant shaft doing nothing at all, and contiguous to the up-cast pit. At the bottom of the up-cast there are four underground boilers, and five gas retorts, and according to Mr. Forster's statement they consume one-fourth of the whole amount of air that passes up that shaft. Now, these boilers and gas retorts are fed by fires supplied with air that does not go into the workings at all. It is of the want of proper explanation before the Parliamentary Committees that I complain, because the gross quantity of air stated at 80,000 cubic feet per minute is taken as ventilating the workings, whereas it is admitted that one-fourth of that quantity does not go into the workings at all. I wish to draw your attention to this circumstance, because I consider it one of the greatest enormities in Ventilation. The intrusion of this 20,000 feet of air I state at one-fourth the area of the shaft or 12 feet, whilst the temperature of the shaft is raised above the temperature of the atmosphere from 90° to 100°; which I think you will agree with me is equal to other 12 feet of the shaft. There is therefore 24 feet, at least, to be deducted from the area of the shaft, which is 50 feet, giving only the difference, 26 feet for the actual Ventilation of the Colliery. It was admitted by Mr. Forster that, with only two boilers, the current of air was as great, or nearly so, as with four boilers and five retorts, so that notwithstanding this increase of the boiler fires the return air of the mine had not increased in proportion. If more boilers were put down, a proportionate quantity of fresh air would be required to sustain them, and therefore I contend, if there were ten or more boilers put down, there would be no air at all passing through the mine (*laughter*). The uncon-

sumed smoke which comes from these boilers is of a very different character from that which comes from a well-adapted Furnace. There being a great disparity between the statement of us the Inspectors and that made by Mr. Forster before the Parliamentary Committee, I feel that it would be very desirable to have them examined before a new Committee, nominated partly by Mr. Forster, and partly by this Institute.

The PRESIDENT—The subject of Seaton Delaval Colliery having been introduced I think it requisite to say a few words upon it. Mr. Dunn says there is an anomaly between the experiments of the Inspectors and the statements of Mr. Forster in his evidence before the Parliamentary Committee in 1849. I have gone very minutely into the experiments made by those gentlemen, and have also read over the evidence of Mr. Forster very carefully, and I have come to the conclusion that there is no anomaly at all. I think Mr. Forster was fully borne out in the statement he made to the Committee when he made that statement. I think besides, that the character of that gentlemen is a sufficient guarantee that he would state nothing but what he knew to be true. But, in addition, to his evidence we have an examination of the Colliery by Mr. Thos. John Taylor who I am sure every gentlemen here will give credit for correctness; and we find that Mr. Taylor's examination fully corroborates the statement of Mr. Forster *(hear, hear)*. We have also an examination of it by Professor Philips, a gentlemen of high scientific attainments, and then a Government Commissioner, and we find too that his examination corroborates the statement of Mr. Forster before the Parliamentary Committee. We have, again, the fact that the experiments made by Mr. Dunn and the other Inspectors were made in 1852, but every gentlemen will know the difference between making experiments in 1848 or 1849 and making experiments in the same Colliery in 1852. The circumstances at each period may be very different indeed. I could point out a great many instances of such differences within my own experience, and if Mr. Dunn will read the experiments I have made attentively, he will find in the same Colliery we have 120,000 and 130,000 cubic feet of air passing under certain circumstances; and in the same Colliery, under other circumstances, we have 230,000 cubic feet. Therefore, the experiments made at the Colliery in 1849 may have been attended with very different results from those made in 1852 (*hear, hear*). Both experiments may have been, and I have no doubt were, correctly made, and there is therefore no want of analogy between them. If you take into consideration the effect of the resistance of the air in passing through the mine, owing to the in-

creased extent of the workings since 1849, the difference is readily accounted for. The effect of the number of boilers would be measured by the temperature of the shaft. Four boilers would give out more smoke than two, and there may be other circumstances to account for the difference. Mr. Dunn states that he did not find the temperature of four boilers more than that with two; therefore, the fact of there being four instead of two boilers would appear to have nothing to do with the matter, except as regarded air required to work them. I am anxious to make these observations because it has gone abroad that there is a difference in effect between what Mr. Forster stated before the Committee, and what has subsequently been found to exist. In my opinion there is nothing to derogate from the statement of Mr. Forster in 1849, by the experiments which have been made now.

Mr. DUNN—The statements were made in 1852 as well as at the former period.

The PRESIDENT—But the statement of 1852 was based upon experiments made in 1849.

Mr. DUNN—No; upon experiments made after that.

Mr. STEPHENSON—Certainly not.

Mr. T. Y. HALL—I believe the manager of the colliery which exploded recently at Wigan is an advocate of the Steam Jet, and from what I have read of the evidence it appears he resorted to the old mode of using water to produce a current of air. Besides, I believe, he has not had the Steam Jet applied to the colliery where the workings appears to have been greatly extended since he gave his evidence in favour of the Jet before the Parliamentary Committee.

The PRESIDENT—I believe the Steam Jet is applied at Ince Hall, where several experiments have been made by Mr. Dickenson and others. Those experiments have, I understand, been made the subject of a report to Government and will be printed, but I believe the Steam Jet was not applied at the pit where the accident happened.—

Mr. STEPHENSON—I referred to the subject of the Steam Jet as one that had been exhausted, but I did not apply that observation to the ventilation of coal mines, for I am very far from thinking that has been exhausted; but, so far as the comparison between the merits of the Furnace and the Steam Jet goes I think it has been exhausted by the very able and elaborate experiments that have been made (*applause*).

The PRESIDENT having observed that there was now nothing further before the meeting.

Mr. Boyd suggested that a resolution, recording the decision of the meeting on the question which had been submitted to its consideration, should be adopted.

Mr. Stephenson suggested that such a course would lead to the committal of the Institute, which it was at all times desirable should be avoided, a plan that was followed in other similar institutions with which he was connected. Although individuals came there to express their opinions, as they were entitled to do, and he was glad to hear them express those opinions, it was better that the Institute itself should not be pledged to any opinion, for it would only lead to caballing which would have the effect of destroying it in a very short time.

The President said—the suggestion made by Mr. Stephenson was quite in accordance with his own opinion.

Some conversation then arose on the importance of extending the benefits of the Institute to overmen, underviewers, and others interested in mining operations. The President explained that the subject had already engaged the attention of the Council, and measures were being taken for effecting that desirable object.

The meeting then separated.

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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING

ON FRIDAY, MAY 6TH, 1853.

Newcastle-upon-Tyne:
PRINTED BY ANDW. REID, 117, PILGRIM STREET.

1853.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

MONTHLY MEETING, FRIDAY, MAY 6, 1853, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the Council having been read,

Mr. Thos. E. Harrison, C.E., Mr. Thos. Sopwith, F.R.S., and Mr. Telford were elected members of the Institution.

A paper on the Ventilation of Mines, and of the Gases in Mines, and on working Pillars, was read by Mr. William Barkus, Sen.

The PRESIDENT then invited an expression of opinion on the subject from any of the gentlemen present, observing that the paper was one of considerable practical importance and interest, and had been drawn up with great care and ability.

Mr. THOS. JOHN TAYLOR inquired if Mr. Barkus was aware when the practice of splitting the air was first introduced?

Mr. BARKUS said he thought about 1826, or from that to 1830.

Mr. TAYLOR thought the practice might be traced to 1823, but he was not aware of its being in existence earlier.

The PRESIDENT said, with reference to that part of Mr. Barkus's paper as to gas being found in less quantities in very deep mines, such as Monkwearmouth, than in more shallow mines; that Monkwearmouth Colliery was near the bottom of the coal basin, and it was remarkable that in coal near the bottom of the basin there was less gas than in coal in a higher situation, the reason of which appeared to him to be, that the carburetted gas being extremely light would naturally escape into the more elevated parts of the mine if allowed to do so, and would be replaced by

the carbonic or other more heavy gases. At Harton Colliery, which was also near the bottom of the basin, the workings were comparatively free from gas, whereas in Hilda Colliery immediately adjoining, but on a higher level, there was a much greater discharge of gas than at Harton; and so at Jarrow Colliery, the more deep parts of that colliery evolved considerably less gas than the more elevated parts, the latter discharging very considerable quantities. The same result seemed to take place at the deep colliery of Seaton, which was comparatively free from gas. The free passage of the gas from the bottom of the basin or lower parts of it, towards the more elevated, would of course be regulated by the comparative freedom from interruptions or breaks in the strata from dykes, &c., but the facts were worth the enquiry and investigation of the Institute.

A lengthened discussion then took place as to the particular mode adopted by Mr. Barkus in removing the pillars at the Whitwell Colliery, as described in his paper, particularly as to taking a lift or breadth of coal headways, or at right angles, to the line of the wall face, instead of working by taking a jud along to the wall face; and more particularly as regarded the mode of placing the chocks to protect the workmen, and the operation of the superincumbent strata upon them, in which Messrs. Taylor, Anderson, Hunter, Wales, and others took part.

In taking away the breadth of coals of 8 or 9 feet in width headways, Mr. Barkus explained that it was taken away the entire width of the wall face. The tram road was laid down next the coal, and the chocks placed between the tram road and the goaf, with props put in between the chocks when required. When the working reached the extremity, the deputies commenced removing the chocks, beginning at the furthest end, and in doing so, they placed one row of chocks as close to the coal as they could all along the face, to prepare for another lift, or breadth of coal being taken away. He explained that the roof being extremely hard and solid, he had found it very difficult to break the roof by the chocks in the usual way, by keeping the two rows of chocks along the face as it is the usual manner, the weight of the roof pressing them into the thill so firmly before the hard roof is broken, that they were expensive to get out; whereas, by drawing the chocks out, the hard sandstone roof was broken off by the solid coal all along the face as the chocks were removed.

It was observed that the row of chocks which Mr. Barkus placed close against the coal would be interposed between the solid coal and the goaf in breaking the strata, and would be then pressed into the thill, or covered up with the falling roof; but Mr. Barkus observed that the roof being

extremely hard, did not break square down along the face, and that this row of chocks operated as a protection to the men in working the succeeding lift. It was also objected to this mode, that only a limited number of men could be let work the coal at a time, having only the breadth of the lift to work instead of the breadth of the whole face; but Mr. Barkus explained that he only adopted this mode of working where such a number of men were sufficient, and that the system of drawing all the chocks along the entire breadth of face as each lift was successively taken off, and thus causing the solid coal to operate in breaking the roof, especially when it was extremely hard and firm, though attended in some respects with inconvenience and disadvantage, was well worth the attention of the members of the Institute; and he further stated, that he produced a greater proportion of large coals in working it headways than in the boardways direction; and likewise that it should be considered, that this was not a pure long wall mode of working, but a mode of working thick and large walls on the long wall system with chocks.

The PRESIDENT stated, that he hoped the example set by Mr. Barkus, of laying before the Institute the result of his experience, in however limited a sphere, would be followed by other members of the Institute. They were essentially a practical body, and what they wanted was practical information on all the different subjects of their profession, and he therefore trusted that this was the beginning of a similar class of papers on the subject of working coal, and on the ventilation of the mines.

Mr. LONGRIDGE then presented a model of a swing door for the tramroad air courses, so constructed as to be self-acting and not requiring an attendant. The door opens in the centre, being in fact two doors meeting in the centre, and being hung on rising hinges, falls close as soon as the trams have passed through. Mr. Longridge stated that he had had these doors in use at the Barrington Colliery for more than twelve months, and that he found no difficulty in the ponies passing through them, that they even trotted through the door without stopping. He observed that when the ordinary door swung upon one set of hinges, and fell against a fixed door post at the other end, the ponies often run against the door posts with the harness, and that his door swinging from the centre or middle of the tramway, the ponies kept the middle of the road and so pushed the door open.

The PRESIDENT then said he had another subject to bring before the meeting of considerable importance to the trade. They were aware that in 1852 a Committee of the House of Commons had been appointed to enquire into accidents in mines. They would also have observed, that Mr.

Hutchins had given notice of his intention to move for the appointment of a similar committe this session, with a view if possible, to elicit some means of preventing such accidents. One of the principal objects of the establishment of this Institute was, that of endeavouring to ascertain how far such accidents could be prevented; and therefore, it became a duty incumbent upon them to aid all in their power the labours of any committee appointed for so benevolent a purpose.

It is understood that the principal heads of enquiry to be made by this committee will be as follows:—

HEADS OF ENQUIRY.

"The ventilation by Furnace, Steam Jet, or any mode, either in use or which may be suggested as an improvement to those now generally adopted.

"The capacity and size of the airways and the best modes of carrying the air through the workings to the upcast shaft, so as either entirely to clear the goaves of foul air, or to leave as little in them as possible, and to prevent what may remain from escaping into the workings so as to cause accidents by explosion.—The methods of supporting the roof and sides so as to prevent as much as possible the recurrence of accidents from falling masses of materials.—The best mode of winding the men up shafts so as to lessen their risk by the breakage of ropes, chains, or parts of the winding machinery, and any other precautions which are necessary to lessen the number of accidents which occur.

"As to the Safety Lamp, whether the Report of the Committee of 1852 on that subject is considered correct, and whether since that any new discovery has been made which will tend to the improvement of the Safety Lamp.

"As to the system of inspection, whether it is considered advisable or necessary to have Government Inspectors, and if so, whether or not it is thought the present number are sufficient, and if not what increase is suggested.

"It will be observed that in coroners' verdicts, in at least 99 cases out of 100 a verdict of "accidental death is returned; this may be accounted for by the state of the law, which gives no discretion to coroners' juries, who are either obliged to return a verdict of accidental death or manslaughter.

"Also as to whether some law should not be made enabling a jury to assess damages in case of carelessness, or to assimilate the law to that of Scotland.

"Also as to whether power should not be given to magistrates or to the Secretary of State, on the representation of the Inspectors, to levy fines on the owners of collieries, where necessary precautions were not taken to prevent accidents; and also upon the workmen who uncover their Safety Lamps in dangerous situations, or commit any other reckless act so as to endanger the lives of their fellow workmen.

"Also as to what system can be adopted which would work best for the establishment of schools for the children of workmen, and funds for the relief of themselves in case of sickness, and of the widows and orphans of those who may meet their death through accidents."

Many of those topics being of great importance to the trade, it appears desirable that they should form the subject of discussion by the Institute. The council have had the subject before them, and recommend that such discussion should take place at the next meeting on the 3rd of June, the honourable Member having appointed the 31st inst. for bringing forward his motion. The heads will be printed with the proceedings of this meeting, and be placed in the hands of the members of the Institute in sufficient time to enable him to come prepared to enter upon the discussion on the day in question.

Before concluding, there was one question which was also of great importance, viz., whether the Davy Lamp was a safe lamp or not. They would have observed that the Committee of 1852 had reported that the lamp was an unsafe lamp, and that the flame passes through the gauze when the lamp is moved at a certain velocity. Now, it was extremely advisable to ascertain whether this is the case or not, and if it is unsafe, under what circumstances it is so. Considering the hundreds of workmen who were daily working with those lamps in atmospheres which either is actually explosive, or is at any moment liable to be explosive, it was of infinite importance that it should be ascertained in a practical manner whether the lamp is a safe one or not. He had constructed an apparatus to test the lamp in the Killingworth Colliery, and he trusted, before the meeting, to be able to state the result, and he would be glad if any of the members of the Institute would favour him with their company to witness the experiments.

The meeting was then adjourned until Friday, the 3rd of June.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

ON THE

VENTILATION AND GASES

OF

COAL MINES,

AND THE

WORKING OF PILLARS.

BY WILLIAM BARKUS.

Newcastle-upon-Tyne:
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1853.

ON THE

VENTILATION AND GASES OF COAL MINES,

AND THE

WORKING OF PILLARS.

THE following observations may be deemed more historical than interesting to many of you. They have been derived during a long period of practice, and I submit them to you without presuming to point out much improvement in the present modes of working Coal Mines. It will therefore be less interesting to the old experienced miner, than to those who are preparing themselves for such pursuits.

My object is to excite discussion on the various methods of management, already well known to colliery viewers in the district, and have been more particularly compiled to explain to those members of the Institute, who have so much distinguished themselves in mechanical and chemical science, who are not practically experienced in mining, to enable them to join in our discussions, and assist us in our endeavours to arrive at the most perfect and safe plan of conducting such operations.

You are aware, gentlemen, that the natural ventilating powers of a mine vary with its depth, arising from the increase of temperature as we descend below the surface, and tending to afford increased facilities for increasing the current of air in the mine, corresponding in some degree with its requirements.

The inflammable gases are usually most plentiful at the greatest depths, (at least as far as my observations have enabled me to judge) there are exceptions, as at troubles, open gulletty stone forming the roof or floor of the coal, where reservoirs of gas pent up under great pressure are frequently met with; however, this rule is said to be departed from at Monkwearmouth Colliery, where (I have been told) the quantity of carburetted hydrogen gas discharging from the coal is very moderate. The deeper mines have also, in addition, a greater length of column of heated

air in the upcast shaft, giving to the downcast additional preponderating power. This has been fully explained by our President during the Steam Jet discussion.

On examining memoranda made when I was in connection with the late Mr. George Hill (a gentleman whose ability as a mining engineer, and his scientific attainments are well known to many of you). In reference to the ventilation of Team Colliery in 1815, I find that we were satisfied with about 8000 cubic feet per minute, in the Betty Pit low main workings, now we have 40,000 cubic feet per minute, occasioned by the goaves being extended in the working of pillars, by splitting the air and apportioning it in separate streams to the respective districts, thereby shortening the runs, and reducing the resistance,

The depth of the downcast being 74 fathoms,
and the upcast, 63 Do.
Diameter of the shafts 7 feet 9 inches.

The air-courses in 1815 being in no part less than 36 square feet of sectional area; the length of run at that time exceeding 20 miles; the waste was divided into three and four board courses, the middle boards being set apart for stowing, leaving a creeping road over where falls occurred, and maintaining secure, two open air-courses.

In those pits there was at that time (when working the whole mine) a considerable quantity of inflammable gas discharging from the Tyne Low Main Seam, most particularly under the eastern part of the estate, where its depth (adjoining to Sheriff Hill) is about 120 fathoms. The air in its progress became gradually more deteriorated as it proceeded through the workings, by being deprived of a portion of its oxygen in supplying the requirements of life to the workmen and horses employed, and by collecting in its progress, carbonic acid, gas, and other impurities, tending to reduce the inflammability of our much dreaded enemy. The progressive change indicated by the candle being, gradually from a short blue top on the flame in places near the downcast, or first of the air, to a long brown top mixt with blue in the return, as it approached the upcast.

At the time above referred to, as at present, it was the common practice to give the return air from a blower, or a foul board, a long run before naked lights were permitted to be introduced amongst it, by which means the inflammable gases became more diffused in the passing current, and consequently further reduced below the firing point.

Should the exception before referred to, as reported at Monkwearmouth Colliery, be correct, namely, that little inflammable gas is there met with, we may be led to infer that high temperature has something to do with

expelling it at a certain point. At any rate it is a subject well worth our attention.

The justly celebrated Professor Johnson, of the Durham University, a few years ago noticed a new mineral, which he named *Hatchetine*,* supplied to him by Mr. Hutton, from Urpeth Colliery; and I think the Professor stated that it was obtained from the fissure of a dyke in a solid state, assuming the consistence of wax, of a brown colour; which he thought became volatile when exposed to the action of the atmosphere or perhaps decomposed by the action of those galvanic currents, supposed to be passing through the earth in dykes. About the same time my son, (who had previously been attending Professor Johnson's lectures) found a brown waxy, or resinous substance in the fissure of a dyke at Waldridge Colliery, resembling the above description of *Hatchetine*. This substance, when exposed to the flame of a candle, burnt freely, and gave off a fine pure light coloured blue flame, apparently of intense heat. From that circumstance, I have frequently been led to imagine, that a substance of this nature may exist in a liquid, or finely powdered state between the facings of the coal in firey mines, where it may become aërial, when subjected to the action of the atmosphere, or other means; and when deposited in open gullets in large quantities, may probably supply those immense discharges of carburetted hydrogen gas, occasionally met with, and which continue during a long period. I mention this speculatively in order to attract your attention, so that due consideration may be given to it. The subject is interesting, inasmuch as it may lead to the discovery of the source from which those gasses are supplied by the operations of nature, during so long a period, as several blowers have been known to exist.

Carbonic acid gas is more abundant in some particular beds of coal than in others; and, together with the superabundant nitrogen, produced in the operation of the working of a coal mine, are usually ascribed as being the cause of the difference, in appearance of the colour, and length of top, shewn on the flame of the candle, when used as a test of safety. The carburetted hydrogen gas, in the Hutton Seam, or Tyne Low Main is supposed to be the most pure, and consequently displaying a much shorter and more pure blue light-coloured top on the candle than in any of the other seams usually found above it in the Newcastle coal formation, before arriving at the firing point. I have known an overman brought up and accustomed to the top, in the Tyne High Main, very much deceived, when put in charge of a pit's workings, in the Hutton

* Transactions of the Natural History Society, Newcastle, Vol. II., page 394.

Seam; and, on the contrary, a viewer or overman taken from the Hutton Seam, and put in charge of a pit's workings in the Tyne High Main or Wear Main coal, to be very much alarmed at the appearance of the top on the flame of the candle, long before the atmosphere of the mine arrived at the firing point. More than one accident has been supposed to have arisen, in my recollection, from these causes.

The rage of the present day seems to be, to vie with each other in having the greatest possible quantity of air passing down the pit; but we must be careful to have it applied in such a manner as to perform its ntended duty before it is allowed to return to bank.

The air at the bottom of the downcast is divided into apportionments in accordance with the requirements of the respective districts in the pit. This is effected by passing the currents through regulators, or single apertures, leading into or out off each district, the size of which are regulated by slide shutters to accommodate the different lengths of run and other circumstances. Those divisions are again frequently subdivided when the air arrives within the district it is intended to ventilate. This system tends to shorten the run, and lessen the ordinary friction, or as it is now termed the "drag." By such means a much larger quantity of pure air is conveyed into the mine, affording to the workmen a more healthy atmosphere to live and breathe in. However, I may take the liberty of reminding you, that great vigilance and attention is required in a fiery mine, in order to balance equally, the impulsive forces requisite to attain a regular effective ventilation in the respective divisions, varying as they do in length of run, dip, and rise of seam, and other circumstances tending to obstruct its progress, and also atmospheric changes; the latter being indicated by the barometer.

The method of ventilating mines by "split air," as it is termed, was first introduced at Felling Colliery by the late Mr. Hill in the latter part of 1815. Those workings had previously been aired by one Furnace and a single current; however, at that time the atmosphere near the bottom of the upcast became so much loaded with carburetted hydrogen gas, which induced serious apprehensions as to the propriety of proceeding further without increased powers of ventilation.

It was ultimately determined to place two Furnaces at the bottom of the upcast pit, the air to be divided and conveyed in separate streams to each, the one to be applied in ventilating the waste, and the other the working part of the mine.

In the whole mine workings or other places where bratticed air is required to remove impurities, great caution is necessary in the split

system, in order to avoid too much contraction of the sectional area of the air-way. Board end doors ought to be cautiously applied, if absolutely necessary, where bratticing is required for preventing too large an accumulation of gas in any part of the mine; as it must be borne in mind that, by contracting the passage below the arranged minimum standard of the air-course, the resistence of the air will be increased, and the district will consequently be deprived of its due quantity, and thereby endanger other parts of that district. In order to elucidate more fully my meaning, I will assume that the minimum sectioned area of the air-course in a mine is 36 square feet in a four feet seam; the four yard boards in such a seam will only be equal to 48 square feet, and therefore, when a brattice in such a board is placed to direct the air to the face, it is not likely that there will be more than 10 or 12 square feet behind it to contain the current. Under ordinary circumstances it will be found better to reduce the passage way for the tubs, to about 4 feet in width, or 16 square feet of sectional area, and direct the remainder up to the face. Peculiar cases frequently occur where more air is required than it is possible to apply when a sudden discharge of pent up gas is let loose; however, it is necessary at all times to attend to the state of the return air whilst loaded with an additional quantity of carburetted hydrogen gas.

During our experiments at Killingworth, on the 4th of December last, when both Furnace and Steam Jets were in operation, the quantity of air passing between the downcast and upcast was found to be nearly 40,000 cubic feet per minute, through a sectional area of 36 square feet. This passage was reduced to $7\frac{1}{2}$ square feet of sectional area, when the current then passing between the downcast and upcast was ascertained to have been reduced to 25,000 cubic feet per minute, and the water guage rose from $1\frac{1}{4}$ inches to $2\frac{1}{2}$ inches.

Permit me, gentlemen, also to direct your attention to the Furnace. I think it may be improved by gradually enlarging the area of the archway from the fire towards the shaft, in order to accommodate the increased bulk of the air occasioned by the rarefying power of the fire.

There is another subject I have undertaken to submit to your consideration, which is of considerable importance to the proprietors of coal mines, inasmuch as by increasing the quantity of merchantable coal produced from our valuable coalfield, it is proportionately adding to the value of the property containing it, and by whatever means this is accomplised, due attention ought to be given to any plan that can be devised which is likely to accomplish such a purpose.

When I first commenced as a young viewer at Team Colliery, under the late Mr. Steel, in 1811, the pillars were at that time working in the yard coal seam, or what is usually called the main coal on the Wear, under the south-east angle of the Ravensworth Estate, at the depth of 75 fathoms below the surface, laid out in 14 yard winnings. The boards were driven 4 yards in breadth in the whole mine or first working over, and the pillars left for a second working, 10 yards in thickness, and holed at 24 yards; the headways 2 yards in breadth.

After each of the districts were exhausted in the whole mine, the pillars were then commenced at the extremity of the coal, intended to be worked from the respective shafts in the estate, or from the boundary barrier, and brought back by what is usually termed jenkining, viz., by driving a narrow working up the middle of the pillar, leaving as much coal in stooks, or on each side of the working, as was found necessary to support the incumbent strata and protect the barrow-ways during the process of such second working. This mode was in general practice at that time, and it may be unnecessary to state, that much loss of coal was sustained thereby, arising from the stooks being pressed down into the thill, and occasioning a sort of bending down of the roof, and preventing the stone or incumbent strata above the seam from breaking off, so as to rest upon the floor of the mine in a detatched state from the strata reposing upon the unworked pillars. This frequently caused the board rooms in advance to fall, and its influence was often so much extended as to cause a general creep in the vicinity of the goaf, and so crushing the coal in the pillars around it.

This system was induced in order to admit of the edge of the goaf being partially ventilated where the men were working, (the period I refer to being previous to the invention of the safety lamp.) The Steel Mill being at that time the only instrument we had to enable us to examine the waste, and keep in repair the air-courses.

About the year 1815 or 16 it was discovered that, with the assistance of the safety lamp, a more effectual mode of working might be adopted, and thereby obtain the whole of the coal. To accomplish this object, the pillars were left of greater thickness, proportionate to the depth of the seam, in order to form sufficient barriers of themselves to resist the effect of the pressure from the goaf. The tramways were laid along the headway course next in advance of the broken workings, and the coals conveyed from the juds or working on branch railways up the old boards to the headway, and from thence to the crane or main railway, the pillars being worked back either by judding or taking away the whole breadth,

or dividing them into two or three portions, and removing the coal away in lifts or portions driven down to the goaf in accordance with the requirements of the roof.

This mode of working enabled the workers of the mine to obtain the whole of the coal contained in the seam.

The late Mr. Buddle introduced a further improvement, by dividing the districts to be worked into panels, surrounded by barriers, adding thereby to the aggregate strength of the pillars, and leaving a portion of whole coal to mix off with that obtained therefrom in the second working; and although no increase of quantity could be obtained, yet a greater proportion of round coal was got, in consequence of the resistance to the overhanging pressure of the strata above the goaf being more effectual.

At Team Colliery an immense improvement was effected by adding to the size of the pillars; they were increased to accord with the respective depths from the surface, varying from 20 to 120 fathoms, and as the quantity of round coal obtained from pillars is in all cases less than from the whole coal, the additional yield from the barriers became of great importance.

The object of my remarks being intended to induce discussion, and elicit facts from others in reference to a system which I shall now describe, and which, though old in the southern coal fields, it is new in this, viz., the long wall system of working coal.

The first experiments that I had an opportunity of witnessing were at Team Colliery. The pillars had been left in the olden times of the usual size, under an excellent grey metal roof. They had been successfully worked for many years upon the principle last described, and nearly the whole of the coal was extracted from a given space; however, in consequence of the flattering reports in circulation, setting forth that so much more round coal was obtained by the Lancashire process, we were induced to try it in those pillars with the aid of chocks and props.

The place selected was in the Tyne Low Main Seam, lying at the depth of 50 fathoms, the walls were 8 yards, and the boards 4 yards in width, nearly all upstanding. Three walls were commenced with, in a breast, and the men were protected by two rows of chocks, assisted by metal and common props. Here we very soon found that the pressure from the goaf became so great upon the back chocks as to prevent their removal, and to spread its influence up the old boards, causing the roof to break to an extent to induce its abandonment, and resort to the old system again.

The next place I tried was at Whitwell Colliery, in the Wear Low Main

Seam, at a similar depth to that last referred to from the surface. I was induced to make this selection, in consequence of the seam having *a very strong sandstone roof lying next above it, several fathoms in thickness;* the walls or pillars were 10 yards, and the boards 5 yards, the merchantable part of the seam being only 2 feet 4½ inches in thickness, with about 6 inches of coarse refuse bottom coal, in which the kirving or incision was made, together with 8 inches of bottom stone required to be taken up in order to admit of the use of tubs and ponies, 3 feet 6 inches being required for ending up the tub and filling at the face, 8 cwt. tubs being in general use.

This plan again was ultimately abandoned, as we found no increase in the yield of round coal (which was the object principally aimed at,) the cost of labour being also increased, arising from the additional quantity of bottom stone to be taken up and stowed behind the chocks, together with the inconvenience of obtaining the latter, *arising from the roof bending over towards the goaf without affecting a fracture,* thereby crushing the stooks in approaching the working headways, and producing a tendency of creep.

The same effect was experienced in the Hutton Seam, in another part of the pit. The old system was again resorted to, of supporting the roof with props, and working the pillar and stall method.

During those experiments, we were preparing a district in the whole mine in the Hutton Seam, which had partly been worked the first time by boards 4 yards, and pillars 12 yards in thickness, *with a strong post roof* 3 feet thick next above the coal, and above the post the usual alternations of metal stone and post up to the Low Main. I left every other board, which increased the pillars to 28 yards in breadth, and holed the walls at 60 yards.

After holing the walls in the manner described, we again commenced to work the pillars the long wall system, by taking off 3½ walls in a breast, leaving a sufficient quantity of coal next an air-board driven parallel with the boundary of the estate, in order to secure a return for the air on the inbye side of the goaf. In this manner the coal was entirely taken away out of a space equal to 96 yards by 40 yards when we got the first fall. During this process the men were protected in the ordinary way, by two rows of chocks between the face and the goaf, set in piles of 2 feet lengths of the usual description, made from round timber partially squared, or made flat on two opposite sides, and placed 4 feet distant, together with a supply of common props to apply in case of need, in order to guard against unforeseen occurrences.

After the first fall we soon found the pressure of the incumbent strata above the goaf to bear so heavily upon the back chocks, and simultaneously with the rising of the thill, to force them into the floor of the mine. The back chocks thus became so much nipped as to prevent (or cause much difficulty in) their removal. We ultimately deemed it inconvenient to proceed further with this mode of working, consistent with the safety and economy of the mine, and therefore abandoned it.

The next experiment was made by placing a single row of chocks set close into, and along, the face of the jud or breadth of face, in piles of the above description, placed four feet distant, the entire breadth of the pillar, in order to get hold of the sound unbroken stone, and allowing the roof to fall close up to the chocks or face of the coal. We then commenced with a headways lift or working, of 8 or 9 feet in width, and thus worked off the coal in that direction until we reached the further side of the pillar. By this mode of working, the roof was firmly supported, and no movement or danger was indicated until the working extended across the whole breadth of the face, and until a holing was effected at the extreme end into the board room.

The chock deputies then commenced, after the hewers had left the place (generally at nights), to remove the timber forward, preparatory to beginning the succeeding lift or working.

The chocks were removed in the following manner, viz.:—Two men of experience were selected, with an assistant to remove the timber for them to where it was wanted. They commenced by examining the roof in the usual way by *jowling*, and in the event of any loose stone being discovered, props and chocks were kept in readiness to support it previous to any of the main chocks being removed. They then placed two or three spare piles of chocks against the coal at the inbye end of the heading, under the unbroken roof, and proceeded to remove the inmost pile of chocks next the goaf, and then placed the third or fourth pile in rotation as they progressed outwards, until the whole were removed forward, and the succeeding heading or working put in readiness for the hewers to resume work on the following morning.

This mode of working has been continued for some time, and has been deemed most satisfactory when compared with the other methods I have before described.

You are aware of the difficulty of determining upon the best plan of removing the pillars in a coal mine before necessary experiments have been made to ascertain it, arising from the variety of material composing the roof and floor of the seam, and the difference of stratification that generally occurs (no two places being alike); and as the question before

you is interesting to all parties concerned in the working of collieries, most particularly to those who have the direction of such operations, under this impression I have been induced to submit those experiments to your consideration, in order to elicit facts from those who have had more experience than myself in the prosecution of this new system of working the coal, consistent with safety and economy, and also as to the propriety of following out those experiments upon the principle I have before explained.

The system of thus protecting the men by chocks, and working the coal in the manner last described—when contrasted with the method of removing the pillars by judding or taking away the coal, the entire breadth of the face, protected by props, I have found to be much more safe and economical *under a strong roof.*

When it is considered that a common prop 4 inches diameter is only equal to 12½ square inches of sectional area to bear against the roof, and a solid pile of chocks 2 feet square presenting a bearing-up surface equal to 576 square inches, it will be apparent that a single pile of chocks will contain timber equivalent in bulk to 46 of such props, and be more effective in supporting the incumbent pressure; and as a single row of chocks, consisting of 16 piles (as at Whitwell Colliery), are applied to each jud, it will appear that timber equal to 736 props were applied to support the roof in each place, with other props in addition placed where it was thought necessary by the deputies in charge.

In conclusion, gentlemen, I beg to compliment you on the favourable opinion so generally expressed by the public on the objects we have in view, and also to the increase of our members; but most particularly I congratulate you on the acquisition we attained at our last meeting when joined by Mr. Robert Stephenson (the son of a justly celebrated and worthy sire whom we all knew), who has been bred, brought up, and educated amongst us, with a thorough knowledge of the arduous duties we have to perform. He will have many opportunities of correcting misrepresentations, (in the prominent position he now holds) that frequently arise amongst theoretic gentlemen at a distance, who are ignorant of the nature of our arduous and dangerous pursuits.

We may now consider ourselves fairly represented in Parliament, and I trust that, when our proceedings are better known, practical experience will be placed in a much higher position than it has been hitherto.

WILLIAM BARKUS.

Low Fell, Gateshead, May 6th, 1853.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING

ON FRIDAY, JUNE 3RD, 1853.

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1853.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

MONTHLY MEETING, FRIDAY, JUNE 3, 1853, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

THE minutes of the Council having been read, John Evans, Esq., of Dowlais Iron Works, was elected a member of the Institution.

The PRESIDENT said he believed the present meeting was intended to discuss the heads of inquiry, which were to come before the Committee of the House of Commons, on Accidents in Coal Mines; and, in addition thereto, he expected to have had to lay before the Institution, the conclusion of a paper, by Mr. T. J. Taylor, on Water Blasts in Coal Mines. Mr. T. J. Taylor, however, was unavoidably absent in London, and therefore they could not have his paper on this occasion. The Secretary of the Institution had received a letter from Mr. Woodhouse, with heads of the evidence which that gentleman proposed to bring before the Committee on Accidents. These would be read to the meeting, but before these were gone into, Mr. Reid would submit to the meeting an instrument which he had received, for marking time in making experiments and observations.

Mr. REID then exhibited a small instrument in a circular brass box with a dial plate at the top, having a long pointer revolving in seconds, with a lever so constructed as, by touching a spring at the side of the box, the end of it descends into a cup containing an unctuous substance, which it imprints upon the dial, where it makes a dot, and then goes on again. Besides being extremely useful in recording correct time, by the rapid pressure of the finger, the observer not having his attention taken from the subject of experiment, Mr. Reid stated that among the various

purposes for which it was proposed to be used, was timing horse-races, the observer being able to register the time at which each of the horses passed the winning post, and thus ascertaining the exact time which each occupied in the race. It was stated to be the invention of a Frenchman, who was about to take out a patent for it.

The PRESIDENT and several of the members expressed their approval of the instrument, and of its utility in marking time in experiments on the velocity of currents of air in mines.

The PRESIDENT observed, that at the last meeting he had told them he intended making some experiments at Killingworth upon the Safety Lamp. He was sorry he had not had time to do so to the extent contemplated, having been in London for the last week or ten days. Although he had not conducted a sufficient number of experiments to enable him to arrive at a correct conclusion on all the various points required, yet he might mention he had proved that the flame passed through the meshes of the gauze in inflammable air, when the lamp moved at a certain velocity, and when the wire had attained a certain state of heat. He had a box made about three feet square, and about sixteen inches in depth, inside of which the lamp was placed, at the end of an arm extending from a spindle in the centre, with which it was made to revolve. The box was filled with inflammable air from a blower, and then the lamp was placed upon the end of the arm, and turned rapidly round within the box. The lamp was allowed to become red hot before it was moved, and the number of revolutions and the time occupied were correctly taken. When the lamp was moved at the rate of about eleven feet per second, the lamp being exceedingly hot, the flame did not pass. It was then moved still more rapidly in another experiment, and it was found that the flame did pass, as it exploded the gas inside the box, there being, of course, no other light in the box but that of the lamp; and to prove that the gauze of the lamp was not injured, it was again used in another experiment, in which the lamp did not explode the gas, though it was moved at considerable velocity. The velocity was not very accurately obtained when the explosion took place, as the apparatus was not so perfect as to give the correct measurement at a high velocity; therefore, he could not speak with any degree of certainty as to the velocity at which the flame would pass through the gauze under the circumstances described. He thought at the time the flame passed the lamp, it was moving at from fifteen to twenty feet per second. He was getting the apparatus improved, so as to ascertain the velocity correctly, and also in what state of temperature the wires of the lamp has

attained when it explodes. It was necessary, he remarked, to ascertain the latter point, because when the lamp is not red hot, or even at a dull red heat, and when it was moved at considerable velocity, they could not get the flame through. It was not altogether the velocity with which the lamp moved which made the flame pass, but the degree of temperature of the wires and the velocity combined. When the lamp was moved rapidly for a second or two, he could not within that time get the temperature sufficiently high to pass the flame; it was only when it was moved rapidly round for eighteen or twenty seconds, at the rate of thirteen or fourteen feet per second, and when the wire became not quite a white heat, but a very bright red heat, and when almost the whole of the lamp was in this state, that the lamp exploded. When the experiment commenced, the wire was of a dull red heat, similar to that of a lamp in an inflammable mixture in still air; as it was put into motion the temperature increased, and the wire became of a bright red heat, and the temperature gradually increased as it was whirled round, until it exploded. The rapidity of the motion was such that the eye could not follow the lamp, and the appearance of a complete circle of fire was produced. It was very important to know at what temperature and velocity the gauze of the lamp would pass the flame; and he intended to carry out the experiments so as to determine those points. He expected by the next meeting to have those experiments completed, and he would then lay the result before them.

Mr. Boyd—Ought we not to have the exact proportion of gas and fresh air in the box at the time of the experiment?

The President—Yes; but in the case referred to, he had not the means of mixing the air accurately, so as to ascertain the exact proportions. All we did was to insert a pipe from a blower inside the box and so render the air in the box inflammable. By means of an apparatus he had now got, he should be able to fill the box with any mixture of gases he might think proper. It is very satisfactory to know, as the result of these experiments, so far as they have gone, that it would be very difficult indeed for any person, unless wilfully to raise the temperature of the wires in an inflammable degree so as to cause the flame to pass the gauze. It could only be done by swinging the Lamp rapidly round at the extremity of the arm, for a period of fifteen or twenty seconds, at the rate of fifteen feet per second, and which could only be done wilfully.

Mr. Mathias Dunn said he held in his hand a memorandum of Sir Humphrey Davy, made in 1816, with respect to the flame of the fire-damp; it was printed on the back of a paper entitled "Suggestions arising from inspections of wire gauze lamps in their working state in mines," which

had been prepared for circulation in the mining districts. The note was dated Hesleyside, Sept. 10. and was as follows:—"I have shewn in a paper, printed in the transactions of the Royal Society, that the power of heated wire gauze, to permit the passage of the flame of coal gas, is directly as the size of the apertures, and to a certain extent, as the velocity of the current: I say to a certain extent, because by a current of a *certain velocity*, flame is extinguished. A very slight motion will pass the flame of coal gas through wire gauze, having less than 400 apertures to the square inch, even when it is heated to dull redness; but a very strong current, and an ignition above redness, visible in day-light, is required to pass the same flame through wire gauze, having above 700 apertures to the square inch; and I have never been able to pass the flame of coal gas or any carbonaceous flame through wire gauze having more than 1600 apertures to the square inch, by any means. The experiments above detailed on the blower (alluding to some other experiments) are the first I have made upon *currents* of *fire-damp*. They prove what I had inferred from its other properties, and they offer simple means of rendering wire gauze lamps perfectly safe against *all* circumstances, however extraordinary and unexpected, and of placing their security above the possibility of doubt or cavil."

The President—In those observations of Sir Humphrey Davy, he speaks first of experiments with coal gas, and then afterwards with fire-damp; these gases are essentially different. He should observe, in addition to what he had stated, with respect to the experiments he had made, that the greatest heat was near the top of the lamp, and of course the flame passed where the greatest heat was. This would shewthat lamps with a less length of wire gauze would be more safe. In the next experiments he should use a shorter wire gauze and a chimney. They would see, however, that a shield at the side and near the bottom of the lamp would be of no use whatever, as the flame did not pass through the wire gauze where the shield is placed, but above it near the top of the Lamp.

Mr. Dunn—Can you state what number of apertures there were in the gauze?

The President—Yes; about 784 to the square inch.

Mr. Barkus—Is it not probable that the part most likely to inflame would be the middle of the gauze where the air makes its exit?

The President—The very great tendency of flame to rise would throw the greatest heat to the top of the Lamp, and the experiment proved that it was so. There was thick glass on one side of the box, and we could see the Lamp as it went round.

Mr. Barkus—I have seen a great many experiments, and it was sup-

posed the explosion inside the Lamp took place at the middle, because there the air is stagnant. The air goes in near the bottom of the Lamp to support the flame, and then passes out near the top; and as there would be a point where the air was nearly stagnant, that was in his opinion the most likely part for it to explode.

Mr. ELLIOTT—I have several times seen a Lamp fire inside the gauze; the heat always commenced at the top and went downwards.

The PRESIDENT—Yes; in the experiments the most brilliant heat was at the top of the Lamp, and lower the heat was very much cooler. After the Lamp is shortened, whether or not the quantity of gas within the Lamp is sufficient to raise it to that degree of heat to admit of the flame passing, will be proved by the result. If any gentlemen have any Lamps which they wish to have tried, he would be glad to subject them to experiments, as the apparatus, he expected, would test them very accurately. The result of the experiments already made, was rather in favour of Lamps with a glass, or those which admitted only a diminished quantity of gas. Stephenson's Lamp, for instance, did not explode, because the necessary quantity of gas to produce the requisite degree of heat could not get into it. Several Lamps with glass cylinders were tried, and they all went out without heating the Lamps much.

Mr. DUNN—That is, when they began to get into a red heat, they went out.

The PRESIDENT—They never got into a red heat, but the flame gradually elongated, and then they gradually went out, for want of the requisite quantity of oxygen. We tried the length of time they would burn in an inflammable mixture before they went out, but we did not think the experiment was satisfactory or conclusive, from the difficulty in subjecting them equally to precisely the same admixture of gases.

Mr. DUNN—I suppose the Davy Lamp burnt longer than the others.

Mr. REID—I always found the Davy Lamp burnt longer than any other. I state that from experience.

Mr. HALL—I happen to be using a lamp in which the air enters in a different manner from any other; it produces a greater light, and is equally as safe as Stephenson's or any other I have seen, and it may have a tendency to obviate the objection you state, that of the flame passing through the gauze. I have not tried it, but I think from its construction it would have that effect.

The PRESIDENT—If you will come and bring your lamp with you the next time we make the experiments, we shall be very glad to give you an opportunity of trying it.

Mr. Elliott—You are aware that Stephenson's Lamp is used to a very great extent, and it is found to answer every purpose required. It goes out at a certain point, when sufficient air cannot get in through the apertures so as to support the flame.

The President—One objection to Stephenson's Lamp is, that when the glass is broken, you have a larger cylinder of gauze for the flame than the Davy Lamp, and the larger the cylinder for the flame the more unsafe the lamp is—the sooner a high temperature is produced. But then, if the glass is broken in some of the other lamps, there is no gauze or insulation of the flame whatever.

Mr. Boyd—The great desideratum of Upton and Roberts in constructing their Lamp was, only to admit air to a certain extent, and when it becomes explosive the light goes out, and it becomes extinguished at a certain point.

Mr. Sinclair—The great defect of Upton and Roberts's Lamp is, that it goes out too soon.

Mr. Hall—My object has been to imitate Mr. Stephenson and Sir Humphrey Davy in the construction of the Lamp, but to keep the light longer in with a better flame.

Mr. Greenwell here read a paper he had prepared on the inflammability of inflammable gases. It was as follows :—

ON THE INFLAMMABILITY OF LIGHT CARBURETTED HYDROGEN GAS.

On Friday, May 27th, I, in company with Mr. Simpson, made some experiments at Townley Colliery, in order to ascertain the effect of placing red hot iron in contact with light Carburetted Hydrogen Gas. The Gas, which may be termed "Washed Gas," as it passes through a drowned drift in the Three Quarter seam of this Colliery, is conveyed by means of a pipe in the shaft to the surface; it then passes through naphtha into a gasometer, and thence to various burners in the shops and elsewhere. There is also a cock between the top of the shaft and the naphtha vessel, whence, when opened, the gas issues in its natural form. The first experiment consisted in placing a bolt, about 2 inches in diameter, heated to a cherry red, in contact with the naphthalized gas, in the smith's shop. The gas was immediately inflamed; in a short time, however, the iron, still at a good red heat, ceased to possess the power of exploding the gas.

Precisely the same effects were produced when the iron was applied to the cock between the pit and the naphtha vessel.

The next experiment consisted in applying a Davy gauze, similarly heated, to the issuing gas. An immediate explosion *inside of the gauze* was the result, and this was repeated several times; the flame, however, did not pass through and ignite the external gas.

From this, it appears, that the *mass* of hot iron applied to the gas was the occasion of its explosion, acting in the first instance by heating the gas, and in the next by igniting it when so heated; for when iron in the condition of wire gauze, although equally hot, was applied to the current of gas, instead of the iron in the first place heating the gas to such an extent, the gas operated in cooling the iron externally; after, however, the gas had passed through the gauze into its interior, it had acquired a sufficient degree of warmth to enable the opposite side of the cylinder, still red hot, to explode it.

I intend making some further experiments on this subject which, when, completed, I shall take an opportunity of laying before the Institute.

Note.—All the gas formed in wet pits, or issuing with water, may be termed in an equal degree with the above, "Washed Gas."

If the above theory be correct, it follows that, when the rapidity of the current of gas is such, that the whole of the quantity passing into the gauze (supposing it to be red hot,) cannot be consumed within the gauze, the surplus, in a heated state, must pass through, and be very liable to explode.

The President—There was a question raised at the last meeting of the Institute, as to whether red hot iron would explode fire-damp, and this experiment shews that it did explode that gas. In the first case, however, the gas passing through naphtha would receive some portion of the spirit, and be thereby rendered more inflammable than it otherwise would be; but in the second case the gas was applied before it passed through the naptha, so that it would be similar to gas issuing from a blower. Whether any increased inflammability was produced by the gas passing through the water, was an important question. But, there was another most important point in these experiments, which was this—the gas, they would observe, did not fire at the first wires, or in passing into the Lamp; the wires, it appeared, had the effect of heating the gas as it passed through, and then when it came to the other side of the Lamp and approached the red hot wires, it exploded.

Mr. Elliott—The gas becomes heated in passing through the first wires, and therefore more inflammable.

Mr. GREENWELL—I may explain that these experiments with the gauze were made with gas after it had passed through naphtha, but, in experiments I made with iron, there was no difference between passing the gas through naphtha and not doing so.

Mr. ELLIOTT—Was there any pressure?

Mr. GREENWELL—There was the ordinary pressure, the same as you see in a burner.

The PRESIDENT—Would it not be well to have the gas analysed? I have sent some of the gas from Killingworth to Mr. Richardson for that purpose, so that the constituent parts may be ascertained.

Mr. ELLIOTT—I suppose the explosion would not be instantaneous—there would be a short interval after the gas was passed through the wires.

Mr. GEEENWELL—It was a very short time—only about a second.

Mr. DUNN—Was there the same degree of heat in the experiments?

Mr. GREENWELL—Apparently so.

The PRESIDENT—It is quite clear that these experiments ought to be carried further than they have been; they are very interesting.

The PRESIDENT next called the attention of the meeting to a document which the Secretary had received from Mr. Woodhouse, comprising heads of evidence which that gentleman proposed to give before the Committee of the House of Commons, appointed to inquire into the cause of Accidents in Coal Mines. The document was then read by the Secretary.

The PRESIDENT said he thought the best way of discussing the subject would be to take each head separately. They were aware that Mr. Woodhouse had most extensive practice as a Mining Engineer, and that his opinion would have great weight with the Committee. The first head of inquiry in the evidence of Mr. Woodhouse was, "The Ventilation by Furnace, Steam Jet, or any mode, either in use or which may be suggested as an improvement to those now generally adopted." The object aimed at in this head, was to get into the pit the largest quantity of air they possibly could. If any gentleman had any observations to make upon the point he should be glad to hear him; he believed Mr. Elliott had been making some experiments which were calculated to elucidate the subject.

Mr. ELLIOTT said he had made some experiments upon the Steam Jet, but they were not in such a state that he could bring them before this meeting. It was very probable he should bring those experiments before the parliamentary committee.

The PRESIDENT—It is fully expected (there having been so many committees upon accidents in coal mines), that the present committee would come to some practical conclusion upon the matter; and, therefore, it was very desirable that all the information possible bearing upon the subject should be laid before them. He had had an opportunity since the last meeting of the Institute, of seeing Struvé's Apparatus working at a colliery in North Wales. It was intended to apply two cylinders, but only one was at present at work. It was constructed according to the plan he now produced, and consisted of a cylinder or airometer 17 feet diameter, the piston being-double acting, with a 6 feet 4 inch stroke. He had had an opportunity of making some experiments to prove its exhausting power. It had been at work for about eighteen months, and he was told that only on three occasions had it been deranged, arising each time from breakages in some parts of the machinery, which was discovered to have been defective; and it was out of use only from eighteen to twenty-four hours on each occasion. That would of course be of some consequence in one of our large collieries here. It was pplied to a pit at the Newminster Colliery (the workings of which were not very extensive), at the top of a shaft about 100 fathoms in depth, the shaft being eight feet in diameter; an experiment was made on the water gauge at the bottom of the pit, between the up-cast and the down-cast, and which would shew the drag of the air through the workings. There was a variation in the effect in the working of the air pump, and between the up-stroke and down-stroke of the piston. The maximum effect of the up-stroke of the piston was 1·25 inches, and the minimum effect was ·75 inch. As shewn upon the water-guage, the maximum effect of the down-stroke being the more powerful, gave 1·4 inches, the minimum being 1·1 inch. The average mean being 1·125 inches. The water-gauge at the top of the pit, close to the pumping apparatus, was found to average 2½ inches. The power applied to the top of the shaft was, therefore, equal to 2½ inches of water-gauge, and yet it only produced very little more than 1 inch at the bottom of the pit. The range of the water-gauge at the top of the pit, where the engine was at work, was from 5 inches to nothing at each stroke of the piston. The quantity of air pumped by each complete stroke of the piston, was 25,000 cubic feet per minute, and the quantity of air in the workings was 22,000 cubic feet. This was about three weeks ago. They were then about to apply the second cylinder or airometer, and it will be a very interesting inquiry to ascertain the difference of effect between the two cylinders and one. He should have an opportunity of seeing them in the course of a

short time, and would report the result. The engine used for working the air pump was a high-pressure engine, with a 12-inch cylinder, having a 3-feet stroke, and the boiler was about 30 feet long, with a pressure of 40lbs. to the square inch. The pulsation of each stroke of the airometer piston was distinctly felt in the workings at a considerable distance from the shaft.

Mr. Reid—How many strokes did the engine make per minute?

The President—The air pump piston made from 7½ to 8 strokes per minute; the steam engine 4½ times as many.

Mr. Elliott—Is the same engine intended to work the other pump?

The President—Yes; but I believe they have made an arrangement to put another boiler up if required.

Mr. Reid—Is there any possibility of ascertaining the quantity of air pumped out of the mine?

The President—The quantity pumped by the airometer, taking the number of strokes per minute, and the area of the cylinders, ought to be 25,000 cubic feet per minute. We measured the air in the workings in the return near the bottom of the pit, and found the quantity was about 22,000 cubic feet per minute. It did not, therefore, realize the actual quantity of air pumped. We tried the temperature of the air down the pit and at the top, and it did not vary more than what was due to the increased depth.

Mr. M. Dunn—I will read you a quotation from a work published by Dr. Howard, of London, giving his opinion on coal mine ventilation. He says—"I believe the best means of ventilating coal mines is by means of wind-mills working above, so as to produce a current of air through the mines, such as is now caused by the burning of the furnaces. It seems that a skilful mechanician could readily construct the apparatus required, with a capacious sucking chimney of hoops and incombustible canvass, or in some such way. If furnaces are used for this purpose, they certainly ought to be above, and without the mine, and furnished with chimneys of some considerable height."

Mr. Greenwell—I think it might be useful to take the sense of the meeting as to the means adopted as an auxiliary power to produce ventilation in cases where the furnace cannot be used, in consequence of an overflow of inflammable air, or of explosions.

The President—I suppose what is now used, namely, the water-fall in the down-cast shaft, is the most effective in cases of emergency, although it may be sometimes difficult to obtain sufficient water.

Mr. Dunn—There is the case of St. Hilda pit, where they are now using the Steam Jet, because they cannot get the furnaces lighted

The PRESIDENT—You are quite correct in saying the Steam Jet is used at present for that purpose at St. Hilda Colliery. The pit has been off work for a long time, and, in consequence of the tubbing in a shaft, which was used solely as a ventilating shaft, having been to take out and replace, part of the workings have been allowed to become filled with inflammable air; and although it was practicable to light the furnace, yet it was deemed more advisable to employ the Steam Jet at the top of the pit, to assist in clearing the working. Although the quantity of air is not very much increased by the Jet, about 3,760 cubic feet per minute, yet still it produces a decided up-cast tendency in the shaft, and so keeps the current constant and certain.

Mr. BARKUS—With reference to Struvé's apparatus put in comparison with the furnace, you say the apparatus gives 22,000 cubic feet of air per minute, but take a furnace producing the same quantity, which is the best method, and the most economical? Which is the most approved of? Which most efficiently answers the purpose? If the furnace is neglected to a certain extent, it still continues to act upon the air, and, though diminished a good deal, the current still passes. The machine is kept to a certain point by parties attending it, and in case of accident to it, the current will cease to pass almost immediately. The two systems should be compared together, and some opinion given as to which of them is the best. Struvé's apparatus is now brought forward as the best way of ventilating mines by machinery, and it is desirable to ascertain whether it actually is so or not.

The PRESIDENT—All these are capable of being determined by experiment and inquiry. I should say the men in the colliery are rather against the use of the furnace, they are so satisfied with the safety of the machine.

Mr. BARKUS—I think few of us would say, from the experience we have had, that Struve's apparatus is superior to the furnace. The steady action of the furnace is a great deal in favour of it.

Mr. ELLIOTT—Whatever prejudice there may be upon the subject, it is quite possible to determine by experiment the comparative merits of each system.

The PRESIDENT—Having been called upon to report on this colliery, it will certainly be my duty to make the requisite inquiries upon the subject, and, after doing so, I shall give you the result and my opinion thereon. My impression at present is, that a properly-constructed furnace would give a greatly increased quantity of air; but I have stated I would not give a decided opinion upon it, till I saw the other cylinder tried.

Mr. HALL—No question it will be a very useful apparatus in case you cannot use the furnace.

Mr. REID—I should say it would be very inconvenient to keep the apparatus many years about a colliery, in prospect of using it in case of accident to the furnace.

The PRESIDENT—I am of opinion that Struvé's apparatus is the best mechanical means for pumping air out of the mine. You get by the use of that machine a greater effective power than by the Steam Jet. The mechanical power of the Jet is less with the same boiler power than the machine.

The next head of inquiry, the PRESIDENT observed, was "The capacity and size of the airways, and the best modes of carrying the air through the workings to the up-cast shaft, &c."

Mr. WALES remarked, that they could not be wrong in having large air-courses, in which opinion the members generally concurred, Mr. DUNN observing, that in his opinion the size should be discretionary, in proportion to the size and requirements of the mine, it being impossible to lay down any rule that would be applicable in all cases.

The PRESIDENT said, the third head related to the methods of supporting the roof and sides of the mines. There had certainly been considerable improvements made latterly, by the introduction of chocks, where props formerly were employed. It might be desirable to go into this matter a little more in detail afterwards. Some persons thought chocks were decidedly the best, others preferred props, while others again thought a mixture of chocks and props the best.

Mr. SINCLAIR, the Secretary, stated that Mr. Woodhouse had promised a paper on Long-walls, and it was probable he would enter into that part of the subject.

Mr. ELLIOTT observed, that there was a great difference in roofs, so that one plan was not strictly applicable to all cases.

The PRESIDENT said, the next head referred to was, "The best method of winding the men up the shafts, so as to lessen their risk by the breaking of ropes," &c. This he supposed had reference to M. Foudrinier's and similar apparatus, for preventing accidents. The subject was briefly discussed, it being observed, that probably some account of the different modes in use would be brought before the Institute, when the subject would be fully discussed.

The next head applied to the "Safety Lamp," which had been discussed already.

The next head referred to the system of inspection—"Whether it is considered advisable or necessary to have Government Inspectors, and if so, whether or not it is thought the present number are sufficient, and if not, what increase is suggested." The PRESIDENT said, the first point to consider was, whether they thought it desirable to have Government Inspectors at all or not, and if so, what should be their duties, so that without infringing upon the responsibility of managers of mines, they would best accomplish the object in view.

Mr. DUNN said, it seemed they were chalking out a great deal of new work for the Inspectors, and yet there was to be no increase in their number. He wished to have the observations in the evidence read over again.

The PRESIDENT having read the extract concluding with the words "in order to make the Inspectors efficient, their whole time ought to be employed for the purpose"—asked Mr. Dunn if that was his opinion?

Mr. DUNN replied that it was.

The PRESIDENT observed, that he thought the Inspectors should be paid according to their merits, but it was certainly important that they should devote the whole of their time to the duties of inspection. There was another point of considerable importance. It was proposed to establish an office in connexion with the Government, through the Museum of Practical Geology established in London, to which all reports of accidents, with plans, &c., were to be forwarded. The Museum of Practical Geology might, in his opinion, be very useful in promoting education, and as a record office for depositing plans, &c.; but he doubted very much the propriety—indeed, he thought it very questionable policy, that of interposing any tribunal, except that of a purely practical one, between the Government and the Inspectors of Mines.

Mr. DUNN said he was decidedly unfavourable to such a measure. If the Inspectors were competent for their business, they ought to do it without the interference of a Board. If they were incompetent, it might be a question how far a Minister of Mines was necessary. The Home Secretary was, in fact, a Minister of Mines at present, but if the Government thought proper, they might appoint another Minister specially to assist the Inspectors, who might thus be furnished with the legal opinions of a law officer of the Crown in difficult cases. On two or three occasions he had found it necessary to put questions to the Government with respect to prosecutions. The question goes through the Secretary of State, who lays it before the law officer of the Crown. If a Minister were appointed specially for Mines, he would be the medium through

whom all such communications would pass. After the publication of Mr. Cayley's report, a copy was sent down to each of the Inspectors, who made their remarks upon it.

The PRESIDENT—Then these remarks will be published I suppose.

Mr. DUNN—I don't know.

The PRESIDENT—They ought to be.

Mr. DUNN—It was considered in the light of private information.

Mr. ELLIOTT—Are the reports of the Inspectors sent to the Government accessible to the public?

The PRESIDENT—Yes, I presume they will all be published.

Mr. DUNN—There are three unprinted, but, I suppose the whole of them will be printed.

The PRESIDENT—If it is requisite to have any medium or board between the Inspectors and the Government, it ought certainly to consist of practical men, capable of judging upon what is brought before them.

Mr. ROBSON—I perfectly agree with the President in that opinion. But, is it desirable to have such an intermediate person? Is not the present system better than the one suggested?

Mr. DUNN—I believe the Inspectors are unanimously against any intermediate person being appointed.

Mr. ELLIOTT—It would be well if the gentlemen summoned to give evidence before the committee could meet in London, in order to discuss the various points that would be brought forward.

The President, Mr. Dunn, and other members expressed their concurrence in this opinion.

The meeting then separated.

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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING,

ON JULY 1ST, 1853.

Durham:
PRINTED BY WILLIAM AINSLEY, 74, SADLER STREET.

1853.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

MONTHLY MEETING, JULY 1, 1853, HELD IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the last General Meeting, and the Council Meetings having been read,

Mr. Geo. Johnson was elected an ordinary Member of the Society.

The following minute of Council was read :—

"That as it appears to the Council, that Friday is an inconvenient day to hold the General Meetings of the Society, they recommend that, after the annual Meeting in August, the Meetings be held on Thursday, and that it be submitted to the General Meeting that it is expedient to diminish the number of Meetings by Vacations at Christmas and Midsummer."

The President said, alluding to the above Council Minute, that any alteration in the general rules of the Institute could only be made at the annual meeting, held at the close of the year, and, that for any proposed alterations to be made at such anniversary meeting, it was required that notice should be given at the general meeting previous ; the next meeting of the Institute to be held in August next, was the anniversary meeting, and therefore any notice of the kind referred to should be given at the present meeting. The only notice which he had to give was whether or not some other more convenient day of the week than Friday might be selected for holding their general monthly meetings. Thursday appeared to be a more convenient day than Friday, because on the former day, many parties were in Newcastle upon business, and could attend the meeting without the trouble and inconvenience of coming again on the

Friday. An alteration of the day of meeting to Thursday would on that account, besides others, be more convenient to many parties than that upon which the meetings were now held. There was another matter which required notice, and that was, whether or not it was desirable to diminish the number of monthly meetings by Vacations at Christmas and Midsummer, as was the case in our universities and other learned and scientific bodies. The members would therefore consider those two propositions recommended by the Council, and come prepared to vote upon them at the anniversary Meeting next month.

The President then read a paper upon Experiments he had made with respect to Lamps.

A number of Lamps, most of which had been used in the course of experiments, were exhibited, and their various properties and differences explained. Dr. Glover being present, the President observed that his Lamp having a single gauze at the top above the glass part, was in fact a Davy Lamp in that part and liable to the same defect as the Davy, allowing the flame to pop through the gauze. It was also shewn that all the Lamps that had glass uncovered with gauze, in testing them, had become broken or cracked. A Lamp was produced by Mr. T. Y. Hall upon a different principle from any other, which he considered would yield a better light, and afford greater security than any other. As intimated at a former meeting, he had prepared a description of the Lamp in writing, which he gave to the President. Mr. Hall having subsequently published a detailed description of his Lamp, more fully than explained in the paper alluded to, it becomes unnecessary to print this paper.

The Meeting then Adjourned.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROCEEDINGS

OF THE

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS,

AT THE

MONTHLY MEETING

ON FRIDAY, AUGUST 5TH, 1853.

Newcastle-upon-Tyne:
PRINTED BY ANDW. REID, 117, PILGRIM STREET.

1853.

NORTH OF ENGLAND INSTITUTE

OF

MINING ENGINEERS.

ANNUAL MEETING. AUGUST 5th, 1853, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-ON-TYNE.

NICHOLAS WOOD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meetings having been read,

Messrs. Fereday Smith, C. Bartholomew, C. E., John Ramsay, John Dumolo, James Cope, James Morrison, William Thomas, John W. Day, Joseph Locke, M. P., and William Stenson, were elected members of the Society.

It was resolved, in accordance with the recommendation of the Council, that, in future, there be a vacation of one month at midsummer and one month at Christmas, and that the General Meetings be held on Thursday instead of Friday.

The report of the Finance Committee was read and approved.

Res olved,

That a Committee be appointed to confer with the various parties representing Literary and Scientific Institutions in Newcastle, for the purpose of arranging for the accommodation of the society in suitable apartments; and also for the purpose of conferring with the Committee appointed, to consider the propriety of establishing a Mining School in the North of England, and that the Committee report the result of such enquiry to the Society.

That the Society is greatly indebted and hereby acknowledges its obligations to the Literary and Philosophical Society of Newcastle, for the gratuitous and handsome manner in which that Institution has accommo-

dated the society with the use of its Lecture Room during the past year; and that a Copy of the Transactions of the Society for the year be presented to the Literary and Philosophical Society, and also to the Natural History Society.

Dr. George Fife, exhibited a Safety Lamp and said, my improved Safety Lamp consists in what I consider, a combination of the best parts of the Davy, Clanny, Stephenson, and Upton and Roberts' Lamps. Thus it has the gauze chimney, (double). The Glass of Clanny, protected by an outer Cylinder of Tale or Mica. The risk of fracture of the Glass being further diminished by the interposition of a Ring of Vulcanized India Rubber, between the Glass and the Metal Frame, the effect of which is to counteract any inequality of expansion between the metal and the glass, consequent on the heat. Air is admitted into the Lamp below the wick as well as by the chimney. This is done by means of numerous perforations immediately above the oil vessel, between which and the wick is an horizontal layer of gauze, (double) as in the Upton and Roberts' Lamp. By this arrangement, combustion is more perfect; no current of air or motion has the least effect on the flame, and should the gas explode within the lamp, the flame cannot possibly pass the double gauze. From experiments made both in the laboratory and in the coal mine; this lamp may be truly termed a Safety Lamp, whilst the light which it gives is very superior to the Davy. When the gauze chimney is single and the gauze heated, flame will pass; with the double gauze this does not happen, as even when the inner gauze is red hot, the outer remains at a comparatively low temperature.

Mr. Mackworth then made some valuable remarks as to the lamps used in Belgium, and shewed an improvement which he had made upon the lamp, and promised to give to the society a more particular description hereafter.

The President—The double gauze of the chimney counteracts the effect of a current of air fanning the flame into a high temperature, and so causing it to pass the meshes; with this exception, and with the addition of the tale around the glass, Dr. Fife's Lamp does not differ from the Clanny Lamp. In the experiments at Killingworth, the flame did not pass the wires.

Mr. Geo. Elliott—I have used the vulcanised india rubber rings for some years in Clanny's Lamp.

Mr. T. Y. Hall exhibited his improved lamp, and explained some alterations he had made. As Mr. Hall has published a detailed account of his lamp, it is not necessary to give his description.

Mr. Thos. John Taylor read the conclusion of his paper entitled

"Proofs of the Subsistence of the Fire-damp of Coal Mines in a state of high Tension in Situ, and practical conclusions to be deduced from this circumstance."

A donation of 21 folio volumes and one portfolio, containing memoranda relating to coal and to the coal trade, and entitled "History of Coal and Mining," was made to the society by Mr. Thos. John Taylor.

Resolved,

That the thanks of the Society be given to Mr. Thomas John Taylor, for his valuable present.

The PRESIDENT said, it only now remained for him to take a short retrospective view of their labours, during the first year of their existence, and of the present state and prospects of the society, and it gave him the greatest pleasure and satisfaction, that he was enabled to make so flattering a report. The profession had indeed nobly responded to the feeling which existed, not only amongst the coal owners in the district, but from the mining interest and the public generally; that the time was arrived, when some more than usual efforts should be made to endeavour to prevent those dreadful calamities which had too often, and were still devastating the mining population of this district, and which were becoming of awful frequency and magnitude in some of the other mining districts in the kingdom. They numbered amongst their members almost all the profession of mining engineers of this district, and likewise some of the most eminent and most extensively employed engineers in other districts; the society now consisted of 120 members. They had likewise received the patronage of all, he might say, of the noblemen and gentlemen connected with the mining interests of the districts. and they had received the special support of the coal owners at a general meeting of that body, and the pecuniary assistance of most of the collieries in the counties of Northumberland and Durham.

Composed of such a number of practical, sale, mining, and other engineers, bringing to bear upon the subject, the united experience of that district where coal mining had not only been most extensively practised, but where difficulties and dangers more abounded than in any other mining district in the kingdom, and supported by such a weight of influence, wealth, and commercial enterprise; the least that can be said is, that they contain within their body, and the patronage they have met with, all the elements of success, and that it rests with themselves, whether they do, or do not carry out the benevolent and scientific objects of the establishment of the Institution.

They must not, however, conceal from themselves, that in the same proportion as they have received support, in the ratio of the deep respon-

sibility resulting from the awful loss of life and destruction of property, by those too frequent deplorable calamities, and in the great importance in a scientific, commercial, and practical engineering point of view, so are they called upon to exert themselves—to put their shoulders to the wheel; and, responding to the support they have received, and keeping steadily before them, the benevolent duties which they have undertaken and the scientific and practical objects which require at their hands, steady progression and complete developement, let them prove to their patrons and to the world, that they are not undeserving the support and patronage which they have received.

And, while they are applying themselves with energy, and with earnestness of purpose, to accomplish all the objects for which they have been established, and which are expected from them, let them bear in mind that they are every day raising themselves in the standard of perfection and usefulness in their profession—they are every day making themselves more fitted to undertake the arduous duties appertaining to their profession, whether considered in a beneficient, scientific, or practical point of view.

It is, however, very satisfactory to reflect, that, in the first year of their labours, they have shewn that they have not overlooked the deep responsibility which they have undertaken, they trust that their labours, as exhibited in their volume of their first year's publication, will be found not without its usefulness as a first step towards the accomplishment of the objects of the Institution, and as an earnest of their desire to merit the patronage they have received.

The subject of Ventilation naturally stood most prominent, and they have therefore occupied several of their meetings in receiving papers on that branch of their duties, and in discussing that subject.—Their labours up to this time on that head has been principally directed to the comparative merits of Steam Jet and Furnace Ventilation, but the ventilation of coal mines is a wide and important field of research, and that which has been discussed and investigated, forms but a very small portion of the entire subject. The mode of working coal by long wall has only been incidentally approached; much yet requires to be done on this head: and we have had a very interesting paper on the tension of fire-damp in sitû; which well deserves perusal and consideration. These, together with the discussions which have taken place from time to time, form the substance of our labours for the first year, and which we trust may not be uninteresting to the general reader, as well as to those more immediately connected with mining.

The PRESIDENT stated that he had, at the opening of the Institution,

pointed out some of the subjects, both theoretical and practical which might well, or which indeed it became the duty of the Institution to investigate; they had only yet entered upon the threshold of those subjects, but the energy with which they had pursued those which they had already grappled with, gave earnest, that the remainder would be followed up with equal perseverence, until he trusted, they raised the society to that standard of usefulness which its constitution, its resources, and the opportunities which it possessed, was expected from it.

In conclusion, the President said he had only to remind them that their prosperity depended entirely upon themselves, they had within their own body, and in the opportunities which the district afforded, as he had previously stated, all the elements of success. They had undertaken the responsibility, the eyes of the whole mining interests of the kingdom were upon them, looking to the result of their labours as the combined experience of the district—and bear in mind, of that district, above all others, where the profession have had the greatest opportunities of acquiring information and experience, and by which, they ought to possess the greatest amount of professional skill and perfection. Let them, therefore, be true to themselves, it only required their individual and collective exertion, and the objects of the Institution would be accomplished.

The meeting then proceeded to the election of officers of the society for the ensuing year, and the following gentlemen were elected:—

President.

NICHOLAS WOOD, Esq.

Vice Presidents.

Messrs. Edward Potter,	Thomas John Taylor,
William Anderson,	Robt. Stephenson, Esq. M.P.

Council.

Messrs. William Armstrong,	John Taylor,
George Elliott,	Thomas Jobling,
J. A. Longridge,	Charles Carr,
P. S. Reid,	Matthew Liddell,
William Barkus, Sen.,	John Robson,
G. C. Greenwell,	James Easton.

Treasurer.

Mr. Edward F. Boyd.

Secretary.

Mr. Edward Sinclair.

The meeting then adjourned.

ANDREW REID, PRINTER, 117, PILGRIM STREET, NEWCASTLE.

NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

PROOFS

OF THE

ERRATA.

For "Tale," in page 4 line 9, read Talc, and again in same page, line 33.

Omit "Sale" in page 5 line 30.

PRACTICAL CONCLUSIONS

TO BE DEDUCED FROM THIS CIRCUMSTANCE.

BY

T. JOHN TAYLOR, ESQ.,

A VICE-PRESIDENT OF THE INSTITUTE.

Newcastle-upon-Tyne:
PRINTED BY ANDW. REID, 117, PILGRIM STREET.

1853.

FIG 1

FIG. 2.

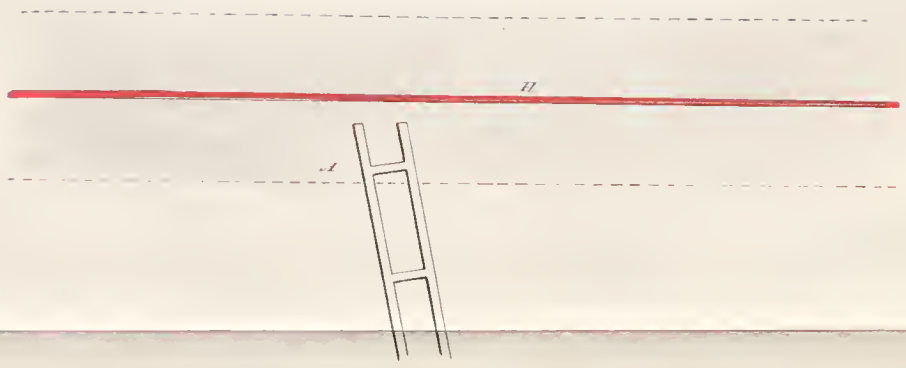
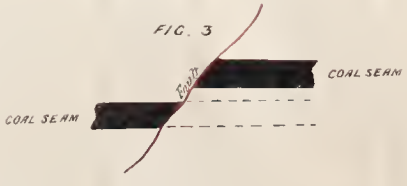


FIG. 4

FIG. 3



REID L THO 17 PILGRIM ST NEWCASTLE

FIG. 4.

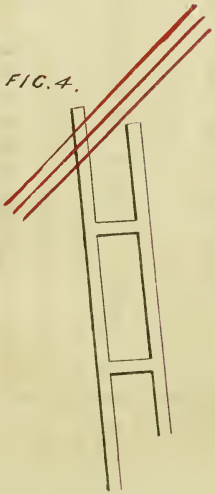
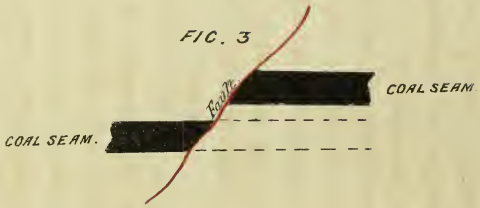


FIG. 3



A. REID. LITHO. 117. PILGRIM ST. NEWCASTLE.

PROOFS

OF THE

SUBSISTENCE OF THE FIRE-DAMP

OF

COAL MINES,

IN A STATE OF HIGH TENSION IN SITÛ.

While pursuing the several investigations which have been made by others or by myself into the origin of explosions in Coal Mines, I have frequently experienced the conviction that we do not adequately appreciate *all* the conditions in sitû of the inflammable gas which causes those explosions. Several reasons may be assigned for this want of sufficient extension in our views.

In the first place, a part of the subject itself is comparatively new, or at least has arisen in the more modern periods of Mining; for it is chiefly in deep mines that one of the forms of fire-damp, about to be considered, is developed; it may be held, therefore, that we have established a generalization of a not unnatural, though certainly inconclusive character, from observations made in localities where the number of facts is really insufficient for the purpose.

It happens also, that even in those situations which are favourable for comprehensive observation, there is in the most of cases, as the workings progress onwards, a tolerably regular evolution of fire-damp, which is uniform enough in the daily rate of issue to deceive us into a belief of its constancy, and to indicate the employment of such remedial measures only as are adapted to the ordinary, and as it may be termed habitual, discharge of inflammable gas, without affording protection in the remarkable cases to which I shall afterwards request your attention.

What I wish to prove is, that there are three distinctive modes in which the fire-damp of mines issues; modes as distinctive as the different consequences produced by them are characteristic of each.

Permitting ourselves to be led by analogy, we have been accustomed to assume, that the case to be dealt with in mines is similar to that of dispersing the miasmata of an over-crowded town, or an ill-ventilated dwelling; yet the analogy would only be correct in the event of the fire-damp of mines being extricated, by a constant process, at a tension equal to, or in the smallest mechanical degree exceeding that of the atmosphere.

If, on the contrary, it can be shewn that only the liberated gas of mines is subjected to this law, while the really more dangerous forms of issue are those of gas in a relatively high state of tension, then a field of research is opened, the investigation of which involves practical results of the very first importance.

By *liberated gas*, constituting the first class of the three under consideration, is meant, that modified form of fire-damp, the issue of which is affected by variations in the pressure of the atmosphere, and which has, in fact, been brought into this state of equilibrium by its established and free communication with the external air.

Fire-damp in this condition is familiar to every one; it is generally lodged in fissures of the roof; it also occupies the goaf spaces of a mine; and consists of gas already extricated, upon which a rise or fall of the barometer produces its corresponding result, still leaving intact those peculiar conditions of the gas which it is the special object of this paper to illustrate.

In connection with barometric changes I may state that I have very carefully compared the dates of 69 cases of explosion, occasioning an aggregate loss of 1452 lives, and including all the severe ones which have happened in our district during the last half century, with the registered heights of the barometer, as recorded in the public institutions, or as made by private observers of this neighbourhood, on the day of explosion, and on the day before, and the day after: and on classifying the results, I have found that 34 cases have happened during a falling state of the barometer, and 35 when it was either steady or rising: and of the cases noted as falling there are 4 of which the fall did not exceed the $\frac{1}{20}$th of an inch, and 13 in which it did not exceed $\frac{1}{10}$th of an inch. Only one great explosion has occurred when the barometer was below 29 inches, and 15 have happened when it was above 30 inches. When these facts, together with the numerous occasions, during a period of 50 years, on which the barometer must have approached and reached the lowest limit of its

range, without the occurrence of explosion, are taken into consideration, it becomes sufficiently obvious, that the form of gaseous discharge which is dependent upon the variable pressure of the atmosphere, is not of practically difficult management.*

The second mode of issue is the habitual one of our deep and fiery mines; it consists of the gas which is evolved in the ordinary course of working, or which, in other words, is in the act of passing into the state of liberated gas from another and highly elastic condition.

This form of gas really subsists in situ in a state of considerable tension, though we are apt to be misled into a contrary belief, because the issue is, in the usual course, comparatively slow and gradual, owing to the difficulty of extrication through the structure of a coal bed. This part of the subject may be illustrated by an experiment of Professor Faraday's, who forced four atmospheres of various kinds of gas into a copper vessel of 100 cubical inches capacity, and attached a thermometer tube of 20 inches in length for the purpose of discharging the contents. Notwithstanding the small size of the receiver, and the shortness of the capillary tube, above $2\frac{1}{2}$ hours were required to discharge the heaviest gas, and nearly an hour to discharge the lightest, down to $1\frac{1}{4}$ atmospheres, though the initial pressure was 60lbs. to the square inch.

Now let us apply this experiment to the extrication of fire-damp. From a fresh worked face in deep mines the gas is discharged by a succession of little bursts or explosions, which throw off splinters of coal; this decrepitation is indicative at once of the force of the gas, and the cellular structure of the fossil; of the power, and the resistance. The cells in question, and the natural lines of cleavage, constitute the means of drainage, the channels by which the gas permeates into the mine; and the emission is gradual, not because the gas is of feeble elasticity, but because the resistance is great in proportion to the tenuity of the passages. The very fact indeed of the gas drainage taking place through what may be termed the capillary structure of a coal bed, is an evidence of the vis á tergo, of the force by which it is propelled.

Advancing another step in the investigation, we are next to consider the third and *really dangerous form of issue.* The drainage process just noticed is liable to be interrupted; and it will not be necessary to describe

* The Barometric observations are either those of the Newcastle Literary and Philosophical Institution made at an elevation of 121 ft. 3 in. above the sea, or of the late Mr. Losh, at Jesmond, a somewhat higher level than the former. The list, though published elsewhere up to 1849, is placed in an appendix to this paper, of which it properly forms an illustration.

the geological features of our coal field at all minutely with a view to shew what are the causes of interruption; for those causes are familiar, and constitute in a greater or less degree, a portion of each working coal field. One of them is the occurrence of *faults*, which, by intersecting and dislocating the channels of drainage, act as dams to the transmission of both gas and water. Basaltic dykes have a similar effect; and not only are these natural barriers obstructive to direct drainage, but they often serve as means of communication to new and distant districts along the line of their course. Here, then, gas is liable to be met with, *which is not weakened by previous drainage.*

The same result may occur upon a local change in the structure of a coal bed; and it may also happen, if the workings progress at a faster rate in point of time than that required for effective gas drainage, a curious topic of enquiry, which, as we shall afterwards see, bears upon the numerical proportion of explosions in the various seasons of the year. Whenever one or other of these conditions obtains, the gas is no longer extricated by a gradual process; but when reached by a working place, is discharged at once, and rushes into the mine with great violence.

That issues of fire-damp do take place in mines with considerable force and suddenness is very well known. Such issues have received a technical name; but we are apt to regard them as being of an isolated character, not adapted for generalisation. The object of this paper, however, is to shew, that the highly elastic state in question *is the normal one of the gas in those situations where no means of escape, and of consequent decrease in tension, have yet been afforded to it:* and that we do not find it constantly developed in this high pressure form, only because the very tension it possesses enables it, so long as the lines of drainage are uninterrupted, to force a passage through the semi-crystalline structure of the coal, and thus to drain off the interior magazines, as we may term them, for want of a better word.

It will be observed, in fact, that the second and third modes of issue are no more than modifications of each other. Both are results of a high state of gaseous tension, their variable forms of issue depending upon a difference in local circumstances. The same line of proof is therefore applicable to both cases, the gist being to shew, that fire-damp really subsists in, or is capable of assuming the great elasticity in question.

In the course of Mining practice, a contingency sometimes occurs which throws much light upon the subject. I allude to that eruptive issue of gas which constitutes what in our Mining language is called a "*Waterblast,*" a sudden and violent outburst of fire-damp from a

drowned pit or staple, with workings or other excavations to the *rise* of the shaft.

The theory of a waterblast is very simple. If a. c. f. Fig. 1, be a section of a pit and workings, where a. c. is the shaft, and c. f. a profile of workings made to the rise; then supposing the mine to be drowned by some accident, such as the overlaying of the pumping engine, or from whatever cause, and filled with water up to the line e. f., the compressed common air occupying the remaining rise space, and the water rising in the shaft up to the point a.; supposing also the water to maintain a constant level up to a; then under these circumstances the gas given out by the mine, must, in order to produce a waterblast, expand by its own elasticity, in f. e. c. until it displaces the water to the plane c. d.

It is assumed in this particular case, for the purpose of simplifying the explanation, that the displaced water flows out at a, or that it is lifted out by some means of drainage employed, so as to be maintained at this level.

After the confined gas thus expands to the water plane c. d., its tension is manifestly measured by the height of water column a. c. in the shaft; since the common atmosphere on a balances the common atmosphere shut up in the mine, and which has again expanded to its ordinary volume.* So soon, therefore, as the tension of the gas at all exceeds the pressure of the water column, an eruption takes place from c. The mode of discharge is variable. When the dry mine space is considerable, a continued issue will probably take place, but where relatively smaller, an intermittent form of discharge is most likely to ensue.

A process of the nature described may obviously be regarded as an experiment on a great scale, in which the height of water column above the point of escape is a measure of the elasticity of the confined gas. I shall now, therefore, endeavour to reduce the matter to a greater certainty by describing a waterblast which took place at Percy Main Colliery, with the details of which I had an opportunity of becoming very well acquainted.

The Bensham seam at Percy Main Colliery is 160 fathoms from the day, and 40 fathoms below the High Main Seam. After the Bensham

* In the waterblast of which a description immediately follows, the common air contained in the mine was almost entirely drawn off by piping, as will be noticed. In this case, therefore, the tension of the gas was equal to the water column + 1 atmosphere very nearly. It is clear that in no case can the common atmosphere confined in the mine, contribute to the waterblast, since if even entirely included it can only exert, after re-expansion to c., a pressure equal to that of the external atmosphere on a.

workings had been prosecuted in one direction to the distance of 1034 yards; in the opposite direction of 924 yards; and in the third, or rise direction to a mean distance of 650 yards; the mine was drowned by a large feeder of water met with in the upper seam, which overlaid the pumping engine power, and gradually filled up, first, the upper mine to the level of where the Bensham Pit was sunk through it, and then flowing into the Bensham workings, also filled those workings, and finally rose up to a height of 42 fathoms 1 foot above the bottom of the Bensham Pit, being about 2 fathoms above the thill of the High Main seam.

With a view to prevent a waterblast, the probability of which had been foreseen, a connected range of pipes was laid up to nearly the extreme rise of the Bensham workings, and carried up the shaft above the anticipated rise of the water, a small pump being attached at the shaft end.

The pipes had the effect of discharging the common air confined in the mine as the water rose, but having become choked they did not perform the second part of their duty, which was to draw off the fire-damp gradually, when the water came to be lowered. In consequence of this stoppage, the tension of the fire-damp on the one side, and the pressure of the water column on the other, were put into direct competition; and the critical point arrived when the buoyancy of the one was just equal to the pressure of the other. This balanced condition took place when the water had been so far taken out, that according to a register of soundings, only 23 fathoms remained in the pit, from which a deduction must be made for the tail or back water extending into the mine, the more so because the means of discharge at the lower end, was not, in this case the shaft, but the furnace drift. I shall allow for the tail water the depth actually found after the waterblast, namely 21 feet, which cannot differ at all materially from the truth, though it may be something too great an allowance, because the water must have increased a little in the mine between the occurrence of the water blast and the first observation made after it was over. Deducting therefore $3\frac{1}{2}$ fathoms ftom the shaft depth 23 fathoms, we have $19\frac{1}{2}$ fathoms of water for the measure of the tension of the gas, when it issued, or in other words when the waterblast took place. The consequences of its escape at this high tension were that it rushed with extreme velocity to the surface, tearing away part of the wood work of the pit in its passage, and causing to issue from the pit's mouth an immense stream of gas. As the gas in escaping had to make its way through the water column in the shaft, and thereby encountered considerable resistance, it occupied many hours in discharging itself; after which

it was found that the water had fallen from 23 fathoms to 21 feet, that is to the point already mentioned, where there is a communication with the mine by means of the furnace drift.

The tension, thus measured by a column of water 19½ fathoms in height, is equal to very nearly 3½ atmospheres, and adding the natural atmosphere,* gives 4½ atmospheres for the tension of the gas at the moment of issue.

The magnitude of the scale on which this proof was exhibited precludes misconception.

The calculated mine space excavated was 5,984,450 cubic feet; the quantity of water remaining in the mine after the eruption was estimated at 1,978,317 cubic feet; the difference of 4,006,133 cubic feet is the volume of compressed gas, contained in the mine at the moment of eruption; multiplying this by 4½ we have 18,027,598 cubic feet for the quantity of gas of the ordinary atmospheric tension produced during the barring up of the mine; but this quantity, properly speaking, requires to be abated, for the common air left in the mine, by 1,196,890 cubic feet, and thus corrected it becomes 16,830,708 cubic feet.

Deducting lastly from the corrected result, the quantity left in the mine after the eruption, namely, 4,006,133 cubic feet, we have 12,824,575 cubic feet of gas of the common tension, for the amount of discharge during the waterblast.

It will be observed that there is no necessity to have recourse to theory in investigating this subject. The fact is before us that fire-damp continued to issue under a pressure of at least 4 atmospheres, and we are not to ascribe this result to any local action or quasi incidental accumulation; on the contrary a large space of workings, upwards of a mile in length, by 600 yards in width, was occupied with the compressed gas; plainly leading to the conclusion that in those mines *where the fire-damp has no means of escape by spontaneous drainage, its normal condition is that of a high state of tension.*

A question arises as to why the elasticity of the confined gas was between 4 and 5 atmospheres, and not more or less? I apprehend that this tension is in the particular case, to be regarded as a *minimum;* for in so large a mine space, where some pillars had also been removed, means of escape might be created for the gas, which did not exist previously to the opening of the mine. It is not improbable even that a portion of it penetrated the interposed water barrier, because aeriform

* See Note (Page 7).

bodies easily find their way by absorption into that fluid, especially under pressure.

These circumstances, rather than a want of sufficient tension in the gas, may assist, in the present state of our information at least, to explain why a waterblast did not take place when there was a considerably greater depth of water in the shaft than that under which the eruption actually occurred.

Being desirous, as already stated, to avoid theory in this, enquiry, I refrain from speculating upon a possible condition of the gases of mines, similar to that realised in the well known experiments of Professor Faraday; yet even on a practical view of the subject, we are at a loss to assign room and space enough for the large volume of gas evolved from our mines, except by assuming a highly condensed form in sitû.

The opportunity is not often afforded of determining the quantity thus issuing from a given mine space; but one marked instance may be quoted. I allude to the piped gas at the C. pit, Wallsend Colliery, which has been evolved from a barred up district of about 50 acres in the Bensham seam for a period of something above 19 years. No particular lines of dikes or fissures intersect this district, so as to occasion an extra-local discharge; the pillars have been partially removed in it, but they have also been removed in various other parts of the royalty; so that the 50 acre tract, the inclosure of which enables us to measure the gas issuing from it, is not, so far as can be judged, likely to yield more fire-damp than those remaining portions of the same field, where the supply of inflammable gas passes off imperceptibly by admixture with the atmospheric current.

The original quantity of gas issuing from the tract described, through a 4-inch pipe to the surface, was 95 cubic feet per minute, according to the statement of the late Mr. Buddle; afterwards it fell to 70 cubic feet, and at the present time is about 34 cubic feet per minute, though, as it is no longer found necessary to keep the stoppings quite tight, some leakage through them takes place underground. Taking, however, an average discharge of 66 cubic feet per minute, which is the mean of the three observations, then the mean annual quantity evolved has been 34½ millions of cubic feet, equal to the solid content of a coal bed, 5 feet thick, and 160 acres in extent, so that in 19 years the capacity of 19 such coal beds has been drained off; or which is the same thing the aggregate volume which has issued, is equal to the content of one bed 5 feet thick and 3,040 acres in extent. Where, it may be asked, does this immense

volume of gas find stowage, unless we assume that it subsists in the mine in a highly condensed or compacted state, significant of its great inherent elasticity?

Other waterblasts might be cited, leading to the same conclusion as that above related; but they are rarely of so great a magnitude as the one I have described, and it being also evident that one sound result is of greater value than several others in which the observations have not been so carefully and minutely made, I shall now proceed to a different class of proofs.

The boring process adopted by Mr. James Easton, at Hebburn Colliery, for the purpose of draining off the fire-damp in a manageable shape, has furnished instances, one of which is deserving of particular notice, because it was tested experimentally.

In the first North Eastern district of the Colliery a boring was put down in new ground to the usual depth of 22 feet, where there is a thin seam of coal. A great discharge of gas ensued: the upper part of the borehole was then widened to admit a 3-inch pipe fitted with a safety valve on the top, capable of being loaded up to 56lb. to the square-inch. The pipe was inserted and wedged, and when the gas pressure was laid on, the valve presently blew off at 30lb. pressure to the square-inch; it continued to blow off up to 40lb. to the square-inch, at which point the thill was forced up by the pressure, and this circumstance, of course, put a period to the experiment.

It will be observed, that neither of the experiments related determines the maximum limit of the gaseous tension: nor is it requisite to fix that limit, because it will be, it is conceived, admitted that the proofs cited are sufficient to make good the position we are desirous to establish; while cases of higher tension would only serve, a fortiori, to strengthen and confirm that position.

We are next to shew that sudden issues of gas do take place in mines under circumstances indicating a high state of tension.

A very clear case occurred in the Pespool drifts, Haswell Colliery. The quantity of air passing through these drifts was 9,760 cubic feet per minute, as ascertained a few days previously: the sectional area of the back drift was 37 square feet, and the velocity of the air current was therefore 4·39 feet per second. Safety Lamps were used in the face—while the hewer was at work in the back drift he heard a loud noise, and immediately retreated to the face stenting, where a sound continued to be heard like that of falling water, occasioned by the rushing out of the gas at the face. The air current which circulated in these drifts having, as

the phrase is, "nothing to do," was employed, after passing through them, in ventilating a district further outbye, where the men worked with candles. The deputy of the way immediately ran to warn these men to extinguish their lights; he then returned, and went through a door leading to the back drift, 310 yards from the face, where, with his safety lamp, he found the air-course foul.

With much judgment he kept this door open; and as the greatest portion of the air current then passed by the shortest run, the progress of the mass of fiery atmosphere was not only thus nearly stopped, but the current passing through the door mixed with, and diluted it (the source being now exhausted), below the firing point. In less than half an hour not a trace of gas was to be found either in the face of the drift or in the district.

In this case the mass of inflammable atmosphere produced by the eruption of gas was, at least 35,000 cubic feet, or about 1,300 cubic yards, being the content of the space of drift extending from the face to the point where the return was examined by the deputy; a quantity that may well be deemed ample enough to account for the heaviest pit explosions which have occurred in the North of England.

The volume of gas yielded may be approximated to by assuming that a certain portion of the above 35,000 cubic feet consisted of it, supposing the least proportion constituting an explosive mixture to be 1 in 12, this would give nearly 3,000 cubic feet of gas; it is probable I think that a larger proportion, perhaps 4,000 cubic feet, consisted of the gas; at all events 3,000 cubic feet at the ordinary atmospheric pressure may be regarded as the minimum amount of discharge.

The air current fouled by the discharge moved at the rate of nearly $4\frac{1}{2}$ feet per second through an aperture of 37 square feet. This rate of current is then, quite inadequate to safety. And here we may ask what is meant by a good ventilation? Is one of $4\frac{1}{2}$ feet per second and consisting of air fresh from the day, as in this case, not to be considered good?

It must be confessed that we are unable to realize any definitive idea, of the proper rate of current, from the statements of those, who have interested themselves in the matter.

Loose notions of more shafts and more air are put forth; but no standard of security is agreed upon. Let us suppose however, that 3 times the quantity of air had been in circulation in this district, which it must be explained was one of eleven districts.

We should then have in round numbers, 30,000 cubic feet of air in a

minute passing along the drift with a velocity of about 13 feet per second. Now supposing the issue to have been made in a minute (and I shall quote further on an instance in which the discharge must have occupied only a few seconds) it is evident that the quantity of air just mentioned would not have been capable of diluting the gas; though it might be very efficacious in making the mixture more explosive than a lesser quantity of air would have done; and in the Haswell case it would certainly have caused an explosion, by bringing the gaseous atmosphere into contact with naked lights before the deputy had time to check its career. But this part of the enquiry does not stop here, other portions of the mine are entitled to have their proportionate increase as well as the district immediately under consideration, and consequently the general, and not merely the local quantity of air, must be increased. Now the additional power required to cause an increased velocity from 4·39 to 13, is, all other circumstances being alike, as the squares of those numbers, that is as 19 to 169 or as 1 to 9.

But the most unsatisfactory part of the affair is, that, with all this increase, we should still be unsafe: and I am really at a loss, or more properly speaking it would appear absurd, to propose a standard of ventilation which, under the circumstances we are describing, would not still leave us in a state of insecurity.

There were three small troubles in advance of this back drift, where the blower was met with, as shewn in fig. 4. Yet the fore drift had already passed through the same faults, without falling in with the blower; so uncertain may be the discharge as regards locality, and so difficult is it to anticipate the effect of a system of drainage, unless carried out in a very minute degree. After passing through the faults in the fore drift without any thing particular occurring, a violent issue of gas is yet met with from the same faults, and in the parallel drift only 12 yards distant.

We may thus perceive the inefficiency of the methods of tapping the gas, proposed by Ryan and others, and are enabled to appreciate the inadequacy of a system of drainage by boring at intervals. Similar remarks apply to those methods of working, the supposed security of which depends upon the principle that subcarburetted hydrogen rises naturally to a higher level. It is not meant to be asserted that such methods are without benefit: on the contrary, each possesses a certain merit of its own; but the objection is, that separately or collectively, they are far from constituting a complete remedy; and by creating a false confidence they are even calculated to produce evils of the most mischievous character.

No trace of fire-damp remained after the great irruption which has been described: in less than half an hour the face was quite clean. Sup-

posing that an explosion had taken place, involving the destruction of the persons who witnessed the issue, a subsequent examination would have led to no satisfactory result, as to the origin of the gas, which occasioned the explosion. The face of the back drift might have been suspected; but a cavity was not visible here; only a mass of disintegrated coal, which on such examination would be found not to yield gas; and so the origin of the catastrophe would have remained enveloped in that mystery which is so common, and we may almost add habitual, an attendant on great pit explosions. As another cause of confusion, we may add that explosion, had it occurred, would have taken place, not in the drift where the blower issued (and which was protected by Safety Lamps), but in the workings ventilated further on, as above mentioned, by the same air current: so that the travel of the fire would have appeared on examination, as leading towards the real source of the disaster instead of away from it. Those who from curiosity or some other motive have followed the traces of a fire, will easily perceive how a circumstance like this bears upon the anomalous and perplexing appearances so often presented after explosion.

The next instance I shall mention occurred in the Low Main Seam, Walker Colliery, near the Jane Pit Shaft; when approaching the "Thistle Pit Dyke," a block of coal, together with the disintegrated coal lying next the trouble, weighing in all about eleven tons, was displaced in a violent manner while the hewers were at work. A very great discharge of fire-damp ensued, which fouled the whole of the workings in that district. The content of drift ways, in which men were working and over which it was *certain* that the foulness extended was 41,681 cubic feet.*

On the first issue of the gas, the Davy Lamp nearest the point of discharge was extinguished by it; the lamps of the other men were put out by them as soon as possible.

After the lapse of 15 minutes the mine was again free from fire-damp. The current of air circulating in that part of the mine was 10,483 cubic feet per minute, moving at the rate of 6·24 feet per second in an area of 28 feet.

Another violent discharge of inflammable gas took place at the same slip dyke, a short distance to the Northward. On approaching it a bore was kept in advance as a precaution against a similar eruption.

The drift had advanced within 3 yards of the trouble; the bore was through the slip, and had penetrated a short distance into the coal on the rise or west side of the trouble without any discharge of gas. The place

* The mine was probably fouled to a considerable distance further, but there were no means of observation beyond the limits given.

was then driven up to the trouble and a portion of coal hewn out of the rise side; the position of the seam having been thus ascertained, the workmen were set on to take down the roof, with the view of carrying up the tram road. Whilst doing this, a quantity of *danty* or disintegrated coal fell from the slip of the trouble, (although the bore had passed close beneath it,*) and a great discharge of fire-damp ensued.

The extent of workings in which men were employed, and over which the foulness extended, was 641 yards in length, with a capacity of 86,306 cubic feet.

Davy Lamps were in use over the whole of this space; and a Deputy and some workmen who were near the extreme point of the workings, had the wire gauges of their lamps at a red heat for at least 10 minutes; as in the former case there is no doubt that the extent fouled comprised a considerably greater mine space than was observed to be inflammable.

The Jarrow example is equally forcible. In it we find the Overman congratulating the Hewers in the drifts where the gas came off, on the good state of the ventilation, and the freedom of their places from fire-damp, only half an hour before the explosion took place, and when the explosion did occur, the Viewer and Under-Viewer suspected it least of all, to have happened in that district, which was at the time *remarkably free from fire-damp.*†

Mr. Buddle has very fully described this explosion in the Transactions of the Natural History Society of Newcastle, Vol. I., p. 184, where a drawing is given of the block of coal forced out by the issuing gas. I examined the district of explosion two days after its occurrence, when the ventilation was very imperfectly restored, and yet no fire-damp was to be fonnd in any part of it.

The space through which the fire of this explosion extended was about 3,300 cubic yards, and if we allow an expansion of about 3 or 4 for 1 by the heat of the explosion we shall have the original volume reduced to 900 cubic yards; it cannot, of course, be stated what might be the proportion of fire-damp contained in this mass; but $\frac{1}{10}$th would give 90 cubic yards, or about 2,400 cnbic feet. I do not doubt that the quantity of gas which caused the explosion was inferior to that of the Haswell issue already noticed.

I may here remark, that, though for obvious reasons, only a vague

* See the observations in Page 13.

† We are here reminded of a matter of practical observation, that in mines yielding fire-damp, its constant and uniform rate of discharge is considered a favourable symptom, because, in fact, such a form of issue indicates an uninterrupted district in advance of the workings.

notion can be formed of the volume of gas, which causes explosion, yet an examination of the district enables us to form some idea, and perhaps we may even say, approximation, to the quantity.

Our researches into this part of the subject must be guided by the traces and travel of the fire, and not by the extent of mine occupied by after-damp, which is diffused much beyond the limits of explosion. In point of fact, the volume of the after-damp is 9 times greater than that of explosive gas, when the latter is mixed with air in such a proportion as to leave no unconsumed residue.*

As a general result, which must, however, be taken with the qualifications mentioned, I may state, that such of the *heavy* pit explosions of the North of England as I have had the opportunity of investigating, have appeared to me to be occasioned by quantities of from 2,000 to 4,000 cubic feet of gas; that is to say, by such quantities as we know by experience *are discharged from a single working place, without warning, in a minute or two, or a still shorter space of time.*

In the foregoing details we are furnished with direct proofs of the high tension of the fire-damp of mines, not only by the observed violence of its discharge in the cases cited, but also by examples in which the gas has been subjected to actual experiment.

We have also contemplated another form of fire-damp, where the gas is in a state of equilibrium with the atmosphere. To these a third may be added, being that of mines which yield no fire-damp.

The distinction between the several cases will be found to reside chiefly in locality.

*It will be observed that the volume of *fire-damp*, not that of of *fiery atmosphere*, is here intended. If the fire-damp constitute 1 part in 11 of the admixture, then the following are the conditions;—

BEFORE EXPLOSION.	
Fire Damp	10
Oxygen	20
Nitrogen	80
Volume.	110

AFTER EXPLOSION.	
Fire Damp	Nil.
Oxygen	Nil.
Nitrogen	80
Carbonic Acid	10
Watery Vapour	20
	110
Deduct watery vapour, which is condensed as the mine cools	20
Volume	90

The above proportions are taken because they are such as work out without leaving a remainder of unconsumed fire-damp.

The after-damp is 9 times the volume of the fire-damp which produced it, and consists of 8-9ths nitrogen and 1-9th carbonic acid gas.

The carbonic acid produced is just equal to the volume of fire-damp consumed.

The watery vapour produced is equal to twice the volume of fire-damp consumed.

Certain seams of coal, at moderate depths from the surface, have lost their fire-damp by spontaneous drainage; in other words, by its escape to the day; it is replaced in those beds by water and carbonic acid gas, which occupy the same fissures or communications that allowed the inflammable gas to escape.

In the second case, the fire-damp has also continued to escape so long as its tension much exceeded that of the atmosphere; and what remains is of relatively feeble expansive power. Here is situated the region of liberated gas, the study of which has betrayed us into an inadequate generalisation of the whole subject.

We have the fire-damp of great tension in the next gradation. So long as this highly elastic gas is eliminated gradually, and by what may be termed a capillary issue, as described in page 5, it is quite manageable. We have, however, seen that even under these circumstances a gradual and continued issue takes place, until the tension becomes very high, provided the gass issue into a confined receiver. And it evidently does not matter, in principle, whether such receiver be the artificial space of a mine barred up by water, or the natural reservoirs of that mine, which are excluded from the open atmosphere.

It does not follow that every such reservoir will yield, on being reached, a stock of high pressure gas; on the contrary the gas may be, and as a general rule is, forced by that very pressure through the cellular substance and cleavage lines of the coal as the workings approach it; and when the reservoir is reached, there may in this case, be little or no gas yielded.

It is thus that an explanation is furnished of a circumstance before adverted to, namely, that assuming a state of great tension to be the one in which the gas of deep mines *naturally exists* in sitû, its issue in that condition ought to be a more common occurrence than it really is. But on reflection, it will be perceived that the tension in question is really the cause of the habitual emission of the gas, before it is reached by the working places, whenever the texture of the intervening mass is pervious enough to permit that emission; for example, if a pair of drifts approach a hitch, H. fig. 2nd, where a cavity exists containing high pressure gas, it does not follow that this "bag" will be found, when reached, to retain its original tension. On the contrary, throughout the space a. the gas may have the opportunity of slow discharge, by permeating through the cleavage of the coal. But if the space A. be sufficiently compact to retain the gas; or if only a single pair of drifts and not a broad face of workings be carried forward into a whole district, (for a good deal may depend upon the surface of drainage exposed,) or, if a fault, as in fig. 3,

occur, dislocating the line of drainage; then the contingencies arise in which issues of gas in a high state of tension will be met with, issues that may take place from the coal seam, which is being worked, or from its roof or thill, or even from another seam not yet opened out, and situated above or below the one into which the irruption is made. The probable remark that sudden and violent issues of fire-damp are not habitual, is thus, it is conceived, fully met. If it be stated, that such issues are not of constant occurrence, neither, it might at once be answered, are heavy pit explosions. At the same time we must especially guard against the assumption that the causes of the explosions in question are of a partial or peculiar character: on the contrary, they are connected, as already described, with a class of phenomena numerous enough to constitute a part of our ordinary mining operations: and further than this, they may even be dependent, as we shall see, upon the rate at which the excavations progress, independently of those phenomena.

A particular circumstance here arises for notice: while we meet with many known examples, proving the subsistence of fire-damp in a high state of tension, there are, it must be inferred, numerous other cases in which, explosion having followed the discharge, we are left without a living witness of the actual occurrence.

This painful and remarkable peculiarity should make us attach the greater value and authority to the examples that come to our knowledge, since in the great majority of cases, *the evidence has been, as a consequence of the issue, destroyed.*

It is seldom that so decided a clue is left as in the case of the Jarrow block of coal in 1830, or in that of the Washington explosion of November, 1828, when an eruption of gas broke down the roof of the air-board *behind* the workmen.

On the contrary, owing to the confusion and wreck caused by explosion, it is not surprising, if, in the generality of cases, we are unable to discover a point of issue.

Neither may any fire-damp remain to denote the place of discharge. As gas in a high state of tension equalizes itself at once with the pressure of the atmosphere when the communication is rendered sufficiently free, no trace of the discharge that caused the mischief is even likely to be met with after those explosions which are caused by gas of high tension.

On similar grounds may be explained the great, and otherwise hardly credible, obscurity that so often hangs over these accidents. There is a remarkable uniformity in the character of the evidence concerning them. Frequently the last persons who were in the district of explosion declare,

that every thing was right, that the ventilating current was good, and the mine free from fire-damp; and this kind of testimony, which has, not seldom, been brought down to within less than half an hour of the time of explosion, may be quite correct, yet by no means conclusive of the supposed safety, but on the contrary the reverse, as in the Jarrow case, when the accident was preceded by *a diminution in the ordinary issue of fire-damp,* upon the principle already explained.

Then again, after the catastrophe has occurred, and the cause of it is to be sought into, we may be as much at a loss as before. The issue of fire-damp may, as just noticed, have entirely ceased; but some reason is to be assigned for the accident, and it will, I apprehend, be admitted, that the one suggested is often quite inadequate; as if it were really framed rather because a reason of some kind must be given, than for the purpose of explaining the actual circumstances: yet those circumstances become sufficiently clear when referred to the form of issue contended for.

It has been already stated that some curious results are elicited by arranging pit explosions according to the seasons of the year, in which they have happened.

In the following table the various pit explosions of Northumberland and Durham, are arranged according to the months of their occurrence. The first column contains the explosions of which I have an account, that have happened since the year 1743. Their number is 126. The second column contains those which have happened since the year 1800, in number 93:—

MONTHS.	List from 1743.	List from 1800.
January	4	3
February	3	1
March	7	5
April	11	6
May	7	5
June	15	10
July	9	9
August	11	7
September	10	10
October	16	13
November	15	13
December	18	11

This account, in common with the others we possess, is very defective, and far short of the number of explosions which have actually occurred.

It is for this reason that I have broken the list into two periods, with a view to test one by the other. It may be held fair also to assume, that the omitted cases, being subject to the same producing causes, would present proportions not very dissimilar from those given. Dividing the year into periods of 3 months, and raising the lesser number of cases up to the higher, we obtain the following comparison—

	Distribution according to 1st Column.	2nd Column.
January, February, March	14	13
April, May, June	33	29
July, August, September	30	35
October, November, December	49	49
	126	126

In periods of 4 months they are as follows:—

January, February, March, April	25	21
May, June, July, August	42	42
September, October, November, December,	59	63
	126	126

The last result is curious, being in a regularly increasing proportion, thus:—

For the first 4 months of the year the number of explosions is, as	1
For the next 4 months it is, as	2
And for the last 4 months, as	3*

The explanation of these results is, in my mind, very simple, being referable to a commercial feature in the trade. The collieries of Northumberland and Durham are worked as well for home consumption, as for the supply of markets, the communication with which depends upon a distant, and often precarious navigation.

It has, therefore, been usual for their customers to lay in winter stocks; and these stocks being on hand during the first months of the year, the demand is then short; and *the rate at which the mine excavations progress proportionally slow.*

* There is a disturbance of the order about the month of June, which is, however, still more corroborative of the views taken in the text.

The winter stocks being exhausted, the demand during the next four months is brisker, though not so great as it is afterwards: here then we have the medium rate of excavation, and also of explosion.

During the last four months, besides the increasing demand of the colder season, the winter stocks are to be laid in; and so we have the most rapid rate of excavation, and the greatest number of explosions. The foregoing comparison of seasonal periods and explosions is sufficiently curious of itself in many respects: but my chief object in inserting it here, is to shew the consistency of matters of fact and observation with the positions taken up in this paper; it being evident, that during the latter part of the year, the works progress too rapidly to allow time for the safe drainage of the internal reservoirs, while at the commencement of the year, the contrary is the fact—the results are shewn in the relative number of explosions occurring at each period.

On examining a list of the heavy explosions which have occurred in our district during the last 25 years, we find that in 16 cases out of 18, these explosions have happened in the *whole mine,* that is, in the districts where pillar working had not commenced, for in the whole mine, erroneously considered the safest, naked lights have been, as a rule, made use of, while in the pillar workings, where the ventilation is necessarily less effective, Safety Lamps are employed. The result is that no explosion whatever can be proved, and scarcely one can even be suspected to have taken place in the pillar districts, when Safety Lamps were used in those districts.

It is scarcely necessary to remark upon the corroboration of the principles explained in this paper, thus furnished by the ascertained locality of explosions, for though fire-damp is abundant enough in the pillar districts, yet it is evidently at the first working in the whole or virgin mine, that gas of high tension is most likely to be met with; and accordingly *it is in the whole mine, and by the contact of naked lights, used there under a mistaken sense of security, that great explosions occur.*

It may hardly be necessary here to explain that all explosions are not attributed to direct issues of gas of great tension: on the contrary, it is self evident that a too feeble ventilation, with a gradual extrication of gas, will produce an inflammable atmosphere; but it is contended, and I must submit demonstrated, that this latter type is the one upon which our attention is too exclusively fixed; and that the remedies devised are consequently far from being sufficiently comprehensive to meet the entire case. Further, it does not follow that gas possessing a tension of several atmospheres enters the mine in this state; for it may issue, as we have

seen, either in this condition or at an inferior gradation of pressure, so that great periodical issues of gas may take place without possessing the marked eruptive character, though evolving an extra quantity sufficient to render them highly dangerous.

I must here observe, that no portion of this memoir is intended to disparage improvements in mine ventilation. On the contrary, the most efficient practical development of a ventilating system is held to be necessary, not only in fiery mines, but in those yielding incombustible gases, perhaps equally wasteful of human life. One of the results of the line of argument adopted in this paper is to shew that a superior ventilation is required to dilute and remove the ordinary issues of fire-damp; but what is also contended for is, that we must not attempt to carry ventilation beyond its legitimate object, the real question being whether we are justified in encountering, an enemy of so powerful, and yet so insidious a nature, as the one we have described, without some protection beyond that of a good ventilation; and the facts and arguments adduced in this paper manifestly point to the conclusion that we do require such additional protection, and that to rely solely upon ventilation, is in reality though a not unnatural, yet a dangerous and fatal error. There is no escape from this practical inference, which is a direct corollary from the ascertained fact of the subsistence of fire-damp in sitû, in a highly expansive state.

Our mines are ventilated by a power, which, in favourable cases, is represented by a column of water of 3 to 5 inches in height, say 4 inches as an average. Let us suppose then, that a "bag" of gas possesses the proved tension of 3 atmospheres above the common atmosphere, then those three atmospheres are measured by 1,230 inches of water, being more than 300 times the power of the ventilating column. By what name shall we designate the mistaken confidence which thus puts into competition agents so hopelessly unequal?

But assuming that by a more successful application we are able to increase the ventilating powers in the ratio of 4 to 1, we shall still have 1 to 75 against safety; and if these powers were augmented as 10 to 1, the ventilating agency would still be inefficient compared to this cause of explosion, in the proportion of 1 to 30, even on the datum assumed, which as regards the tension of the gas in some of its states, is doubtless far short of its maximum.

What other means of protection then are we to make use of in dealing with this gas, of high tension? At present, our security against the consequences of its issue, is obviously destined to rest on the universal

employment of the Safety Lamp in our fiery mines. This instrument possesses the advantage of being at hand, and not to be sought for, or invented. Are we not then bound to employ the means of safeguard we actually possess, without waiting for those yet to be discovered, and perhaps it might be added, without blundering, or seeing others blunder on, in a wrong direction; our own opinions being in the meantime treated with something very like contempt, for this obvious reason, that the destruction of life which occurs year after year, is regarded as a sure indication that we ourselves do not rightly understand the subject?

Under the actual system of working by bord and wall, and the subsequent removal of pillars, the largest proportion of coal of deep mines, must perforce be worked with Safety Lamps, and it will be found on making the calculation, that a much smaller proportion than might be supposed of the produce of a fiery mine is obtained with naked lights. I have ascertained by admeasurement on the Haswell Colliery Plan that something more than five-sixths of the entire coal remain after the first working, all of which will have, now or hereafter, to be removed with Safety Lamps. It is true that in the earlier periods of working a colliery, the proportion attained from the whole mine is, for an obvious reason, considerable, and at such periods a change from one mode of lighting to another would be appreciable in a corresponding degree, but the extraction must be viewed with reference to its entire amount from first to last, and under this aspect it is easily shewn that in deep and fiery mines not more than a fifth or a smaller proportion of the aggregate produce is worked with naked lights.

By the Safety Lamp, I mean, either the common Davy Lamp, or some other lamp equally safe. I say equally safe, because I am contented to multiply together the number of days in 37 years of actual trial, in the North of England, by the number of thousands of lamps which have been in daily use during that period, without any well authenticated example of explosion happening, from the employment of the Davy, and to accept the result, as a sufficient testimony of its practical security.

It is of course foreign to the object of this memoir, to discuss the relative merits of various Safety Lamps. I shall only pause here, therefore, to notice an idea, which appears to have obtained possession of the public mind—that the accidents from explosions in mines have not only increased since the invention of the Davy Lamp, but that a reliance on the Davy Lamp is a main cause of these accidents. The fallacy of this notion is manifest from the fact, that so far from our pit explosions having occurred from the use of the Davy, they have really happened where

naked lights were employed, in other words, they have occurred because the Safety Lamp was *not used;* so imperfect is the information, and so strange are the prejudices connected with this subject.

I may remark, that some years ago, I had occasion to make a calculation, along with a gentleman eminent in the trade, of the cost of lighting a pit of 180 hewers, with Safety Lamps from the pit's bottom; and the result was, that the expense of lighting the mine with Davy Lamps in every part, was less, on the aggregate, than that of the mixed method of Oil Lamps, Candles, and Safety Lamps, in actual operation. The distribution of the cost would, however, be different from the present one, if the same system were followed as that now in use for providing Safety Lamps in the broken.

A leading practical objection, which is urged against the employment of the Safety Lamp is, that its use is inconsistent with that of gunpowder for blasting the coal. Admitting that it would be preferable for naked flame to be altogether excluded, it is yet evident, that the chances of accident from the source in question are not great, and that they might be further reduced by proper regulation. In the contemplated arrangement already referred to it was proposed to appoint to every 40 or 50 hewers an inspector who had to examine the place and to see the shots fired. I might here notice the progress which is being made towards another system of working, which will probably result in the employment of gunpowder being dispensed with, were it not already argued that we have no right to await the establishment of that system.

In conclusion, it will be observed, that no speculative or theoretical opinions are introduced into the foregoing pages, the chief object of which, is to place on record the fact, that fire-damp has been proved capable of assuming in sitû, a tension of more than 4 atmospheres. With this datum before us, the practical conclusions to be drawn from it are neither difficult to be perceived, nor at all doubtful in their character. *To depend upon mere ventilation in encountering so powerful an agent must be regarded, as only an abuse of a very excellent principle. We require a further security, and that security must rest at present upon the universal employment of the Safety Lamp in our deep and fiery mines.*

APPENDIX.

Heights of the Barometer on the days of the principal pit explosions in the Coal Mines of Durham and Northumberland, since the year 1803; also on the day before and on the day after each explosion.

The observations are generally three in each day on the registers, and that one is taken which is nearest the time of explosion, when the latter was known to me. The comparison with the day before and the day after is introduced to shew whether the Barometer was in a rising, steady, or falling state at the time of the explosion, see Page 5.

Date.	COLLIERIES.	Killed.	Heights of Barometer.			Wind.	Barometr. Rising or Steady.	Barometr. Falling.
			Day before Explosion.	Day of Explosion.	Day after Explosion.			
Sept. 25, 1803	Wallsend	13	30·30	30·20	30·30		—	* 1/10
Oct. 21, 1805	Hebburn	35	30·25	30·20	30·15	N.	—	* 1/20
Nov. 29, 1805	Oxclose	38	29·90	29·40	29·03	E.	—	* 1/2
Mar. 28, 1806	Killingworth	10	29·90	29·93	30·03	S.	*	—
Nov. 29, 1808	Harraton	4	29·65	29·45	28·90	N.	—	* 1/5
Sept. 14, 1809	Killingworth	12	29·50	29·50	29·80	E.	*	—
May 25, 1812	Felling	92	29·90	29·85	29·80	W.	—	* 1/20
Oct. 10, 1812	Harrington Mill Pit	24	29·35	29·35	29·30	S. E.	*	—
July 17, 1813	Collingwood Main	8	29·50	29·70	29·85	W.	*	—
Sept. 28, 1813	Hall Pit, Fatfield	32	29·95	30·05	30·20	E.	*	—
Dec. 24, 1813	Felling	22	29·70	29·85	29·90	S. E.	*	—
April 5, 1814	Howdon Pit, Percy Main	4	29·60	29·60	29·80	W.	*	—
Aug. 12, 1814	Hebburn	11	29·80	29·60	29·40	S.W.	—	* 1/5
Sept. 9, 1814	Leefield	4	30·00	30·00	30·00	E.	*	—
June 2, 1815	Success Pit, Newbottle	57	29·80	29·80	29·70	W.	*	—
June 27, 1815	Sheriff Hill	11	30·20	30·10	30·10	S.W.	—	* 1/10
Dec. 18, 1815	Towneley	1	28·90	29·15	29·20	S.W.	*	—
June 30, 1817	Low Pit, Harraton	38	29·65	29·50	29·35	S.W.	—	* 1/7
Sept. 25, 1817	Jarrow	6	29·80	29·30	28·70	S.W.	—	* 1/2
Aug. 5, 1817	Wallsend	4	29·50	29·80	29·80	S. E.	*	—
Nov. 3, 1817	Ouston	1	29·70	29·90	29·80	S. E.	*	—
Dec. 18, 1817	Plain Pit, Rainton	27	29·20	28·40	28·70	S. E.	—	* 8/10
July 19, 1819	Sheriff Hill	35	29·40	29·50	29·10	S.	*	—
Oct. 9, 1819	George Pit, Lumley	13	29·70	29·60	29·40	S.	—	* 1/10
Oct. 19, 1821	Nesham's, Newbottle	6	29·55	29·45	28·60	S.W.	—	* 1/10
Oct. 23, 1821	Wallsend	52	28·90	29·00	29·25	S.	*	—
Idem	Felling	6	Idem	Idem	Idem	Idem	*	—
Feb. 21, 1823	Ouston	4	29·60	29·00	29·15	S. E.	—	* 6/10
Nov. 3, 1823	Plain Pit, Rainton	59	29·90	29·60	29·40	S. E.	—	* 3/10
Oct. 25, 1824	George Pit, Lumley	14	29·50	29·10	28·70	S.	—	* 4/10
Nov. 19, 1824	Dolly Pit, Newbottle	11	29·15	29·50	29·40	S.W.	*	—
July 3, 1825	Juliet Pit, Fatfield	11	29·80	29·65	29·80	W.	—	* 1/7
Oct. 5, 1825	Hebburn	4	29·45	29·55	29·55	W.	*	—
Jan. 17, 1826	Jarrow	34	30·35	30·25	29·95	S.W.	—	* 1/10
May 30, 1826	Towneley	38	29·75	29·75	29·65	N.E.	*	—

Date.	COLLIERIES.	Killed.	Heights of Barometer.			Wind	Barometr. Rising or Steady.	Barometr. Falling.
			Day before Explosion.	Day of Explosion.	Day after Explosion.			
Sept. 5, 1826	Heworth	5	29·50	29·55	29·20	N. E.	*	—
Oct. 27, 1826	Benwell	2	29·20	29·25	29·60	N. W.	*	—
Mar. 15, 1828	Jarrow	8	29·95	30·00	29·80	S. E.	*	—
Sept. 1, 1828	New Pit, Houghton	7	29·80	29·70	29·70	S. E.	—	* 1/10
Nov. 20, 1828	J. Pit, Washington	14	29·60	29·50	29·30	N. W.	—	* 1/10
Dec. 3, 1829	Willington	4	29·60	29·40	29·60	S. E.	—	* 1/5
Aug. 3, 1830	Jarrow	42	29·10	29·40	29·00	N. W.	*	—
Jnly 9, 1831	King Pit, Wreckington	3	30·00	29·90	29·90	W.	—	* 1/10
Sept. 20, 1831	Willington	7	29·53	29·53	29·50	S. E.	*	—
May 9, 1833	Springwell	47	29·85	29·60	29·75	W.	—	* 1/4
May 24, 1833	Great Lumley	2	30·10	30·05	29·80	S. E.	—	* 1/20
Nov. 1, 1833	Black Fell	3	30·06	30·07	30·04		*	—
June 18, 1835	Wallsend	102	30·09	30·11	30·10		*	—
Nov. 19, 1835	Burdon Main	11	29·66	29·84	29·85		*	—
Jan. 28, 1836	Downs Pit, Hetton	22	29·91	29·62	29·34		—	* 3/10
Dec. 6, 1837	Springwell	30	30·37	30·12	29·80		—	* 1/4
Dec. 19, 1838	Wallsend	11	30·31	30·22	30·20		—	* 1/10
June 28, 1839	St. Hilda	51	29·89	29·68	29·95		—	* 1/5
June 16, 1840	Haswell	1	30·05	29·87	29·83		—	* 1/5
April 19, 1841	Bigge Pit, Willington	32	29·65	29·65	29·62	W.	*	—
Aug. 5, 1841	Thornley	9	29·60	29·32	29·48	S. S. E.	—	* 3/10
Aug. 17, 1841	Haswell	1	29·78	29·78	29·73		*	—
Mar. 2, 1842	West Cramlington	1	29·21	29·48	29·63	N. W.	*	—
April 5, 1843	King Pit, Wreckington	28	29·29	29·44	29·58	W. N. W.	*	—
Jan. 18, 1844	West Moor	5	30·13	30·05	29·93	W. N. W.	—	* 1/10
Sept. 28, 1844	Haswell	95	30·012	29·852	30·122	W. N. W.	—	* 1/6
Oct. 15, 1844	Coxlodge	1	28·92	28·83	28·82	W. S. W.	—	* 1/10
Dec. 1, 1844	Seghill	2	30·18	30·18	30·07	S.	*	—
Aug. 21, 1845	Jarrow	39	29·47	29·81	30·05	N. W.	*	—
Aug. 15, 1848	Polka Pit, Murton Colliery,	14	29·94	29·96	29·96		*	—
June 5, 1849	Hebburn	31	29·90	29·88	30·08	N. E.	—	* 1/50
Nov. 11, 1850	Houghton Pit, Newbottle	26	29·90	29·83	29·87		—	* 1/11
Aug. 18, 1851	Washington (between 11 and 12 at night	35	....	30·22 at 3 PM	30·25 at 9 AM		*	—
May 6, 1852	Hebburn	20	30·26	30·20	30·07		—	* 1/17
		1452						

	Cases.
Barometer steady or rising,	34
Barometer falling,	35
	69
Cases in which Barometer fell not more than 1/20th of an Inch	4
Ditto in which it fell not more than 1/10th of an Inch	13

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NORTH OF ENGLAND INSTITUTE OF MINING ENGINEERS.

ON

SAFETY LAMPS

FOR LIGHTING COAL MINES.

BY THE PRESIDENT,

NICHOLAS WOOD, ESQ.

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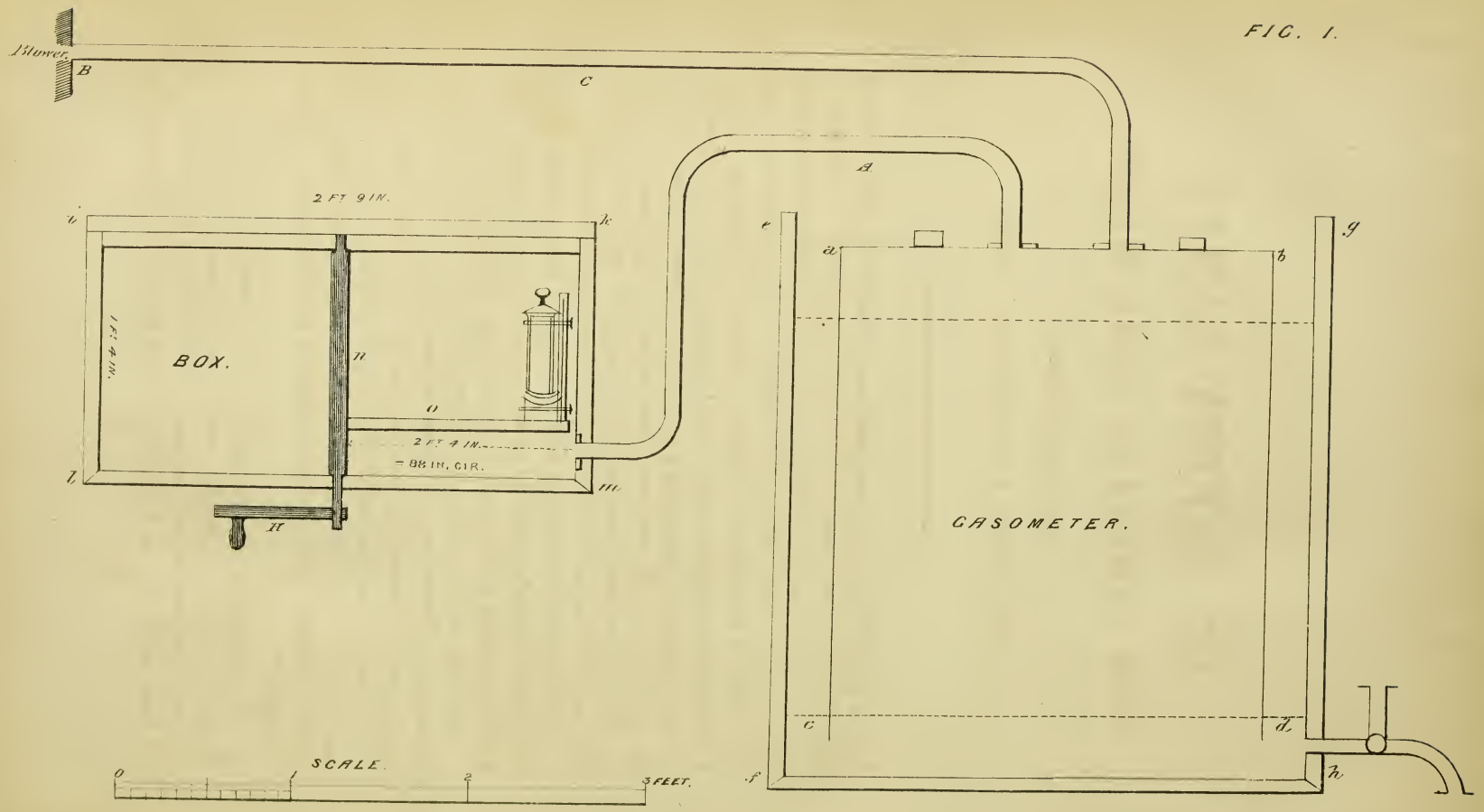
FIG. 1.



REID, LITH.

ON SAFETY LAMPS

FOR LIGHTING COAL MINES.

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In the year 1813 a society was instituted, of which the late Sir Ralph Milbanke, Bart., was president, for preventing accidents in coal mines; and in 1814 the society published its first report, which practically consisted of a letter from the late Mr. Buddle, on the various modes employed in the ventilation of collieries, illustrated by plans and sections. I need scarcely say that a copy of this letter must be in the possession of every member of the society; as besides, containing a description of the then methods of ventilation, most valuable suggestions were made by that able and sound practical mining engineer, on ventilation generally, and likewise on what was required to complete the system.

At that period the only light used in coal mines was the candle, which was described as being made of ox or sheep tallow, with a cotton wick, forty-five candles to the pound, ox tallow being considered the best.

And, when the air in the mine became mixed with inflammable gas, or carburetted hydrogen gas, the mode of ascertaining its existence, and the degree of inflammability was described by Mr. Buddle as follows:—

"In the first place the candle, called by the colliers the *low*, is trimmed—that is, the liquid fat is wiped off—the wick snuffed short, and carefully cleansed of red cinders, so that the flame may burn as purely as possible."

"The candle being thus prepared, is holden between the fingers and thumb of the one hand, and the palm of the other hand is placed between the eye of the observer and the flame, so that nothing but the spire of the flame can be seen, as it gradually towers over the upper margin of

the hand. The observation is generally commenced near the floor of the mine, and the light and hand are gently raised upwards till the true state of the circulating current is ascertained."

"The first indication of the presence of inflammable air is a slight tinge of blue, a bluish grey colour, shooting up from the top of the spire of the candle, and terminating in a fine extended point. This spire increases in size, and receives a deeper tinge of blue, as it rises through an increased proportion of inflammable gas, till it reaches the firing point. But the experienced collier knows accurately enough all the gradations of *shew* (as it is called) upon the candle, and it is very rarely fired upon excepting in in cases of sudden discharges of inflammable gas."

Mr. BUDDLE then goes on further to state, "that the shew upon the top of the candle varies very much according to the length of run, or distance which the current of air has passed through," and that "the same size of spire which would indicate danger in a current which had passed only one mile might be perfectly harmless in a current that had run five or six miles." That "the air course for a short distance beyond, a small discharge of fire damp may be highly inflammable; but by passing a few yards further it becomes so diluted as to be perfectly harmless." And "that long experience and attentive observation are consequently necessary to obtain a thorough practical knowledge of the art."

Such was in 1814 the general mode of lighting coal mines, and the above graphic, and correct description of the mode of ascertaining the presence, and of dealing with the existence of inflammable gas, exhibits the delicate, ticklish, and extremely dangerous method of encountering such an insidious enemy.

When from cases of extreme discharge of gas, or in pillar working, the current of air brought to bear upon the enemy was not sufficient to dilute the gas, so as to reduce it below the inflammable point; then the *steel mill* was resorted to.

The steel mill was an instrument well known in the profession, and consisted of a wheel of steel of about 6 inches in diameter turned rapidly round by a wheel and pinion, a dexterous practitioner, then, by applying a piece of flint to the periphery of the wheel a continuous succession of sparks was elicited, and this produced certainly, at best, a precarious, rather uncertain, but certainly a sufficient light to enable the workman to perform some descriptions of work, and at least to travel pretty well through the workings.

This light, however, required one operator with the *mill* to produce a light for one workman, and hence, as may be supposed, in cases where

the mine could not be cleared of gas to such an extent as that candles could with safety be used; the expense was such that the coal could not be worked at all. And hence, very little pillar working in mines discharging inflammable gas could be practised. Looking at the immense extent of the mines in this district, which was thus rendered incapable of being worked, an extent which was daily, and constantly increasing, in the ratio of the quantity of whole coal excavated in those mines which contained gas. It need scarcely be stated then, that a powerful and accumulating incentive existed, to obtain some mode of lighting mines, to enable such a valuable property to be recovered, and brought into profitable and useful productiveness. Added to this also was the prevailing opinion, that the occurrence of frequent accidents, notwithstanding all the "experience and thoroughly practical knowledge," alluded to by Mr. Buddle, of the persons in charge of the mines, required some mode of lighting mines liable to be suddenly rendered inflammable, which would not in such cases explode the gas.

Some rather severe accidents which occurred about the year 1814, directed public attention, and still more that of the scientific world more strongly to the subject; Dr. Clanny, to whom the mining interest owes a debt of gratitude, was the first to produce a Lamp by which a light could be used in an inflammable mixture of gas with impunity. The insulation of the flame by this Lamp was by means of water, and though the first Lamp which was produced, it was too complicated and cumbrous for general use.

In the autumn of the year 1815, however, circumstances occurred which accomplished the object required, and which has been productive of consequences in coal mining of the utmost importance to humanity and to the mining and commercial interests of the country generally. At the same time, and in distant localities, the late Mr. George Stephenson and the late Sir Humphrey Davy both produced lamps which insulated lights in inflammable mixtures of fire-damp without exploding the gas externally.

It is not my wish, neither indeed is it necessary to arouse the then much debated question, as to which of those gentlemen the mining interests are indebted for the first discovery of this invention. Enquiries then made, and subsequent investigations have, in my mind, satisfactorily established, that both those gentlemen were original discoverers; and that it was one of those, not indeed only cases in science where two persons in distant localities, without communication with each other, stumbled upon, or made the same discovery at the same time, and as in this case,

arrived at the same results by very different processes of reasoning and deduction.

Having been privy to the whole process by which my lamented friend Mr. Stephenson arrived at his discovery, it may not be out of place, neither is it, I trust, an inappropriate opportunity, to give a short detail of the circumstances by which that gentleman arrived at such a valuable discovery.

Mr. Stephenson had observed, that when the fire-damp was accidentally exploded in narrow drifts or passages, a tangible and considerable time elapsed between the instant of explosion at one end, and the arrival of the inflamed gas at the other—that in fact the explosion passed along the drift or passage at a defined velocity—and, reasoning upon this fact, he supposed that such velocity would be dependent upon the area of the drift and that it was possible to arrest the flame; and he thought if motion could be imparted to the current of air in such a drift in a contrary direction and of a greater velocity than that at which the explosion passed —the explosion could be arrested or prevented from passing along the drift. He had also observed, that when blowers of gas were ignited, and lighted candles were placed to windward of such blowers, the flame of the blowers were extinguished by the burnt air of the candles.

He then conceived, as he himself stated at the time, "that if a lamp could be made to contain the burnt air above the flame, and to permit the fire-damp to come in below in a small quantity, to be burnt as it came in, the burnt air would prevent the passing of explosion upwards; and the velocity of the current from below would also prevent it passing downwards."

A lamp was accordingly made of tin, with a hole in the bottom, for the admission of air to the interior of the lamp, and a top perforated with holes. There was also a slide in the bottom to diminish the size of the hole at pleasure. This lamp was tried in inflammable mixtures, and the area of the hole was diminished until the aperture did not pass the flame. It was, however found, that when so diminished, the least quantity of gas in the air put out the lamp. To remedy this, three tubes were used, when it was found that a greater aggregate quantity of air could be admitted into the lamp without passing the flame—and subsequently a lamp with plates perforated with small holes, for the admission of air, was used, which it was found did not pass the flame. At this period of the investigation the reason why the flame did not pass through the apertures was not known. Although it was clear from the number of holes, that the theory of the velocity of the air passing through such

perforations into the lamp did not act in preventing the flame from passing outwards. All this time the burnt air passed through perforations in the top of the lamp.

Mr. Stephenson had now arrived at the discovery that apertures of a certain area did not pass the flame of fire-damp, and had thus discovered the true principles of a safety lamp. Sir H. Davy at about the same time communicated to the Rev. W. Hodgson, of Newcastle, that he had "discovered that explosive mixtures of mine damp will not pass through small apertures or tubes, and that if a lamp or lanthorn be made air-tight on the sides, and furnished with apertures to admit the air, it will not communicate flame to the outward atmosphere," and he subsequently found that "iron wire gauze, composed of wires from one-fortieth to one-sixtieth of an inch in diameter, and containing twenty-eight wires, or 784 apertures to the inch, was safe under all circumstances."

The process by which Sir H. Davy arrived at the above conclusion, is given by himself in a small work "On the Safety Lamp for Coal Mines with some Researches on Flame," which explaining the principles on which the safe insulation of the light is accomplished, is interesting. Sir H. Humphrey states—"I found that it (the fire damp) required to be mixed with large quantities of atmospheric air, to produce explosion; even when mixed with three or nearly four times its bulk of air, it burnt quietly, and extinguished a taper. When mixed with between five and six times its volume of air, it exploded feebly—it exploded with more energy when mixed with seven or eight times its volume of air; and mixtures of fire damp and air retained their explosive power when the proportions were one of gas to fourteen of air; when the air was in larger quantity, the flame of a taper was merely enlarged in the mixture, an effect which was still perceived in thirty parts of air to one of gas."

"I found fire-damp much less combustible than other inflammable gases. It was not exploded or fired by red-hot charcoal, or red hot iron; it required iron to be white hot, and itself in brilliant combustion for its inflammation. The heat produced by it in combustion was likewise much less than that of most other inflammable gases."

"On mixing 1 part of carbonic acid or fixed air with 7 parts of an explosive mixture of fire-damp, or 1 part of azote with 6 parts, their powers of exploding were destroyed."

"In exploding a mixture in a glass tube of one-fourth of an inch in diameter, and a foot long, more than a second was required before the flame reached from one end to the other, and that metallic tubes prevented explosion better than gas tubes."

"In reasoning upon the various phenomena," says Sir Humphrey, "it occurred to me—as a considerable heat was required for the inflammation of the fire-damp, and as it produced in burning comparatively a small degree of heat; that the effect of carbonic acid and azote, and of the surfaces of the small tubes in preventing its explosion, depended upon their cooling powers; upon their lowering the temperature of the exploding mixture so much that it was no longer sufficient for its continuous inflammation."

"This idea, which was confirmed by various obvious considerations, led to an immediate result—the possibility of constructing a lamp, in which the cooling powers of the azote, or carbonic acid formed by combustion, or the cooling powers of the apertures through which the air entered or made it exit—should prevent the communication of explosion."

It is curious to observe the minute difference of circumstances under which those gentlemen arrived at the same result, Mr. Stephenson had observed that candles placed to windward of a blower, extinguished the flame by the azotic air produced by the combustion of the candles. Sir H. Davy, found by applying azotic, and carbonic acid gas to fire damp in a state of inflammability, they extinguished the flame; and hence, both conceived the notion that the burnt air of the flame within, would, in its passage out of the lamp, as one of the causes, prevent the explosion from passing outwards. Then comes the difference: Mr. Stephenson thought, that by admitting small quantities of air through the bottom, the velocity of the current would prevent the passage of the flame outwards, (and this, be it observed, was a fact which Sir H. Davy also discovered, for he had found that in a glass tube, 12 inches long, it required a second before the flame passed from one end to the other); and hence, his lamp was fed first by one hole with a slide, next with three tubes, and ultimately by small perforated holes. Sir H. Davy, on the other hand, finding that the fire-damp required a very high temperature for its explosion, conceived the idea of applying radiating surfaces, through which the flame would have to pass from the interior of the lamp, and by these to reduce its temperature, below that which was required for its continuous inflammation.

Ultimately, iron wire gauze was used by Sir H. Davy, as possessing the greatest radiating or cooling surface, and Mr. Stephenson used small perforated holes, for the admission of the air into his lamp, these small holes acting as radiating surfaces, to reduce the temperature of the flame, as well as in accordance with the principles on which his lamp was originally constructed.

As previously stated, Sir H. Davy found that iron wire gauze of 1-40th to 1-60th of an inch diameter, with 28 wires, or 784 apertures to the square inch, was perfectly safe; and up to this time the lamp bearing his name has been so constructed.

Mr. Stephenson's lamp has been much improved, and the lamp which is now in use, comprises a glass cylinder covered by a cylinder of wire gauze, and instead of the air passing through a perforated plate, it passes through the meshes of the wire gauze. This lamp differs from the Davy lamp inasmuch as in the latter, the air has access through the entire meshes of the wire gauze on all sides, consequently, when immersed in an inflammable mixture, the whole cylinder becomes filled with flame, and if it is continued in such mixture, the wire becomes red hot. Whereas in the Stephenson lamp, the air being only admitted through a few meshes of the gauze within the glass cylinder, the latter preventing the entry of any air or gas from the sides; consequently, a very small portion of gas is permitted to enter, and therefore, the interior of the lamp never being filled with flame, no injury can arise to the wires of the gauze. The small quantity of air or gas entering is, however, productive of another result, viz:—When mixed with gas, there not being a sufficiency of atmospheric air for the combustion of the oil, and not a sufficiency of inflammable gas to support the requisite temperature for its inflammation, the light is extinguished. In the Davy lamp there is a sufficient body of gas to keep up the requisite temperature, and when the lamp is kept in an inflammable mixture, the gas continues burning entirely independent of the combustion of the oil, the wire becomes red hot, radiating the heat sufficient to keep the temperature of the wires below that required for the passage of the flame through the meshes, but still sufficiently high to support the combustion of the gas. There is, however, no acceleration or accumulation of intensity of heat, the wires keep at a dull red heat, if kept in a still atmosphere, and the lamp continues to burn with safety as regards the transmission of the flame through the meshes of the wire gauze.

These are the principles of the two lamps, and I have been a little more minute in the explanation of them, as most of the modern lamps are modifications of one, or the other, or of both; either admitting the air within the lamp unrestrictedly through the meshes of the gauze, allowing continuous inflammation to go on within the lamp, and relying for protection from the radiating property of the gauze as in Sir H. Davy's lamp; or restricting or diminishing the quantity of air admitted into the lamp, as in the Stephenson lamp, and allowing it to go out when immersed

in an inflammable mixture, when the atmosphere does not contain sufficient oxygen, to support the combustion of the oil.

There has, however, recently been a new element brought into operation, which has an important bearing on the construction and safety of these lamps, viz: that of producing a better or more powerful light than the Davy Lamp, and which has led to the rejection of the use of wire gauze as an insulating medium, or the cover of wire guaze over the glass cylinder on the sides of the lamps, and to the employment of glass cylinders alone, to insulate the flame on the sides, the air in all these cases being admitted within and passing out of the interior of the lamp through wire gauze. The principle of insulation, for the passage and exit of the air, is therefore the same as in the Davy lamp, viz: the radiation of the gauze, but then we have only the cylinder of glass, as a protection between the flame of the lamp and the external air. The most extensively used lamp of this description is the Clanny lamp, the construction of this lamp being that of a glass cylinder for the purposes of light, and a wire gauze top.

The Museler Lamp is a lamp most extensively used in Belgium, and does not differ much from that of Clanny, having a glass cylinder for the light, and a gauze top; but in this lamp there is a copper chimney to carry off the smoke from the wick of the burner, and to force the air entering through the wire gauze downwards between the copper chimney and the glass cylinder upon the flame of the burner, the air being admitted through the gauze at the top.

The Boty Lamp is another modification of this principle, having a glass cylinder with a wire gauze top, but in this the air is admitted through a ring of perforated copper at the bottom of the lamp. In other respects it does not much differ from the Museler Lamp.

The Eloin Lamp has also a glass cylinder; the air is admitted through wire gauze near the bottom of the lamp, and is thrown against the burner by a thin copper cap. No other air enters the lamp than that at the bottom through the gauze, consequently it is easily extinguished. Instead of having a cylinder of gauze for the top, this lamp has a copper or brass top, so that the only entry for air is at the bottom, the exit for the vitiated air being at the top through wire gauze. This lamp has not been much used. It has an argand burner, or flat wick.

There are a variety of lamps constructed on this principle, viz., that of obtaining increased light by the use of glass cylinders, all of course of larger diameter than the wire gauze cylinder of the Davy.

Dr. Glover's Lamp has a double cylinder of glass, the air being admitted from the top between the two cylinders, and passing downwards,

enters within the inner cylinder at the bottom of the lamp, through wire gauze, or apertures, and so passes to the burner. The two cylinders are for protection in case of accidents, and the air being passed between the cylinders, operates in keeping them cool. The top of the lamp is wire gauze.

It was my intention to have given drawings of the different lamps; their construction is, however, well known to the profession, and the requisite plates would have extended this paper beyond the limits which I had prescribed to myself in this communication.

I shall now proceed to examine how far the Davy and other lamps can be depended on in practice for safety in lighting mines abounding in inflammable gas.

It is well known to the profession that the safety of the Davp Lamp has been questioned very generally, and more particularly by persons having no experience in its use. Dr. Priara, in 1833, made some experiments to prove its insecurity, but these experiments were made with coal gas, which being essentially different in its inflammability from the fire-damp in mines, could not be considered conclusive; and though the object was to prove the superiority of Upton and Roberts' Lamp, yet even comparatively the experiments were of little value, as the only result found with regard to Upton and Roberts' Lamp was, that when immersed in the inflammable mixture it went out.

The South Shields Committee came to the conclusion "that the Davy Lamp was absolutely unsafe;" "that the Davy Lamp has been found, by experiment and in practice, to explode the external gas by the passage of the flame through the gauze," and that "no doubt can remain that it has been the cause of some of the hitherto unaccountable accidents which have occurred."

Mr. Darlington, in his evidence before the Committee in 1852, says:— "I can state from my own practical knowledge of the Davy Lamp, and from the opinions of miners who have for years worked with the Davy Lamp, that it is not a safe instrument in an explosive mixture under a strong current;" and again, "I have in a mine passed the explosive mixture, but not with a cool clean lamp; it has been at a red heat;" and in answer to the question, "Is it not the fact that dust will fly off in sparks or scintillas, and that one spark would create an explosion?" Mr Darlington says, "There are very numerous instances of accidents taking place that we could attribute to nothing else."

The committee of 1852 state their "concurrence in the opinion expressed directly or indirectly by the committees of 1835 and 1849, and

also with that so strongly expressed by the South Shields Committee, that where a proper degree of ventilation does not exist in a mine, the Davy Lamp or any modification of it must be considered rather as a lure to danger than as a perfect security."

Having had considerable experience during the last 40 years in the use of both Davy and Stephenson's lamps, and having had no well authenticated cases of the lamp passing the flame, and having also, at and since the introduction of the safety lamps, made experiments with gas from blowers in the mines, I had certainly arrived at a different conclusion. Considering, however, that the subject was of vital importance to the mining interests generally, and to the miners more particularly, who venture their lives daily in immense numbers, on the safety of those lamps; I thought it proper to institute a set of experiments, by which the lamps could be subjected to a more severe test than I had ever yet done.

For this purpose a blower was selected in the Killingworth pit, which had been discharging gas for the last 16 years, a gasometer was prepared 2 feet 6 inches inches in diameter, and 3 feet in height, shewn at a. b. c. d., Fig. 1, in which the gas was mixed with atmospheric air in certain proportions required, this was placed within a tub e. f. g. h. in the usual manner, and water was run into the tub for discharging the gas out of the gasometer into the following apparatus,—a box 2 feet 9 inches square and 1 foot 4 inches in depth, i. k. l. m. was placed near the gasometer, with an upright spindle n., in which an arm o. was fastened, as shewn in the drawing; on the end of this arm the lamp p., was fastened, and the spindle was turned round by a handle h., on the outside of the box.

The box was filled with gas from the gasometer, by pouring in water into the tub e. f. g. h., and forcing the gas through the pipe, a. and the gasometer was again filled by letting off the water, the gas being obtained from the blower b., by the pipe c., and the atmospheric air by the pipe a.

The experiments were conducted as follows:—

The lamp was placed within the box, as shewn in the drawing, and the box was filled with fire-damp from the gasometer, the lamp was then allowed to remain stationery until the flame became elongated, and in those lamps where the supply of gas to the interior of the lamp was such, as to keep up a state of combustion, the lamp was allowed to remain at rest until the wire gauze became red hot; it was then turned round, gradually at first, lest the motion should put it out, then accelerated, to increase the intensity of the flame, and so increase the intensity, until the wires were in a state of white heat, and until the lamp passed the flame.

Killingworth Colliery, May 23, 1853.

EXPERIMENTS with the Davy Lamp to ascertain if the flame may be passed in an explosive mixture of fire-damp, and at what velocity.

Davy Lamp, 1st Experiment.—Velocity attained was 9¼ feet per second, without passing the flame.

Ditto, 2nd Experiment.—3 revolutions in 3 seconds, which is equal to a velocity of 7½ feet per second, without passing the flame.

Ditto, 3rd Experiment.—38 revolutions in 36 seconds, which gives a velocity of 7⅔ feet per second without passing the flame.

Ditto, 4th Experiment.—9 revolutions in 6 seconds, which gives a velocity of 11 feet per second, and did pass the flame.

Ditto, 5th Experiment.—15 revolutions in 8 seconds, giving a velocity of nearly 14 feet per second, and did not pass the flame.

It is to be remarked that in the experiments. with the exception of No. 4, the Lamp was put in motion when first full of explosive mixture, and in a comparative cool state, but in the case of No. 4, the Lamp was at a state of red heat, before being put in motion at a high velocity.

Killingworth Colliery, June 6, 1853.

EXPERIMENTS with various Safety Lamps to ascertain if the flame may be passed in an explosive mixture of fire-damp, and at what velocity.

The experiments were made in the box 2 feet 9 inches long, 2 feet 9 inches broad, and 1 foot 4 inches deep, having plate glass windows on one side for observation. In the box was fitted an axle with arms, at the ends of which were uprights about the length of a Lamp, having rings and screws attached for fixing the Lamp. On the under side of the box was placed a handle for turning the axle, working with two wheels, the smaller of which made four revolutions in the time the larger wheel made one. The top of the box was a lid loosely fitted, so that an explosion should not injure the apparatus.

Diameter of circle the Lamp travelled, 28 inches—88 inches each revolution of area. The gas was collected from the blower, mixed with air in the gasometer, and by water pressure forced into the box. In each experiment the lamp, after the gauze being gradually heated to a red heat, was then put in motion.

The following results were obtained :—

No. 1 *Davy Lamp*, after making 160 revolutions in 116½ seconds, and attaining a velocity of 10 feet a second, did not pass the flame. This lamp was again tried, and still did not pass the flame, having made 200 revolutions in 114 seconds, which gives an average velocity of 13⅔ feet a second.

No. 2 *Davy Lamp* was then tried, and the flame passed in two experiments, the lamp having been moved on the first experiment at a velocity of 15 feet a second, making 60 revolutions in 29 seconds; and in the second experiment, at a velocity of 19 feet a second, making 26 revolutions in 10 seconds.

No. 3 *Jack Lamp*, being a common *Davy*, with an outside glass cylinder half way up the Lamp, leaving about 3 inches of the wire gauze exposed. In the experiment the flame passed, but the velocity was not ascertained.

No. 4 *Stephenson Lamp*, without a glass, passed the flame whilst moving at a velocity of 14,6 feet a second, 28 revolutions having been made in 14½ seconds.

No. 5 *Clanny Lamp, copper gauze*, passed the flame at a velocity of 12½ feet a second (12 revolutions in 7 seconds).

No. 6 *Clanny Lamp, with bent iron wire gauze and cracked glass*, was twice experimented with, and at the velocity of 16 and 15 feet a second respectively, did not pass the flame, but in each case the lamp fell off the arms, and was extinguished—96 revolutions in 44 seconds in the first case, and 20 revolutions in 10 seconds in the last. The same Lamp in its damaged state was again tried and moved at a velocity of 12 feet per second (68 revolutions in 29 seconds), but without the flame being passed, the Lamp having become extinguished.

Killingworth Colliery, June 29, 1852.

RESUMED EXPERIMENTS with various Safety Lamps to ascertain if the flame may be passed in an explosive mixture of fire-damp, and at what velocity.

No. 1 *Davy Lamp (1st Experiment).*—In this instance the lamp, after arriving at a dull red heat, was put in motion at a velocity of 15 feet a second without passing the flame, having made 248 revolutions in 61 seconds, the temperature in the box during the experiment varying from 69° to 94° Fahrenheit.

No. 2 *Davy Lamp (2nd Experiment).*—The lamp, after heated to a similar state as in the last experiment, was moved at a velocity of 13 feet a second, having made 52 revolutions in 29 seconds, and the flame passed. Temperature in box varied from 69° to 82°.

A Davy Lamp was afterwards heated to a red heat, and whilst being moved at a considerable velocity, very fine coal dust was thrown upon it by means of a pair of bellows, the nosle of which was inserted in the side of the box. On this being done, the dust produceed small and luminous explosions within the gauze, which would lead an observer to imagine that the flame had actually passed through the gauze, but it did not. Oil was then poured upon the gauze, together with coal dust, so as to put the lamp in a condition as nearly as might be approximating to that it would be in, in the hands of a careless workman. It was then put into quick motion, and continued for some time without the flame being passed.

No. 3 *Clanny's Lamp (1st Experiment)* was tested in the same manner as the Davy Lamp in the first and second experiments, and the flame passed on attaining high velocity, and the glass cracked. The same lamp in its damaged state was again tried and moved at a velocity of 17 feet per second (68 revolutions in 29 seconds), but without the flame being passed, the Lamp having become extinguished.

No. 4 *Boty Lamp* (used in Belgium, being authorized by the Government Inspectors).—This Lamp, after making 12 revolutions in 6 seconds, which is equal to a velocity of nearly 15 feet per second, passed the flame and cracked the glass. Temperature of the box during the experiment varied from 70° to 88° Fahrenheit.

No. 5 *Eloin Lamp*, with a gauze but without the glass. In this experiment, which was conducted in manner similar to the others, the time and revolutions were not ascertained but the flame passed when the lamp was moving at a considerable velocity.

No. 6 *Lamp similar to Eloin Lamp, without a Glass*, was also tried, and the flame passed but the velocity was not ascertained.

Hall's Lamp, with a double wire gauze top tested in the same manner, did not pass the flame, the velocity in this case having been 13 feet per second.

Cail and Glover's Lamp was also tested, and the flame did not pass, but the inner glass cracked.

The mode of conducting the experiments, was a most severe test, such as could scarcely occur in practice, in the first place, the gas being inclosed in a box, when rapid velocity was imparted to the lamp, it would be subjected to an increased pressure of the air from its confinement within the box on the front of the lamp, the centrifugal force imparted to the air by the circular motion of the lamp, would also produce additional pressure to force the air through the meshes of the gauze. It can scarcely therefore, be supposed, that the same velocity imparted to a lamp moved with the hand or carried in the mine, would have the same effect in passing the flame. Not having been able, by any velocity which I could impart to a lamp in a rectilinear direction to pass the flame through the meshes, it was necessary that some snch severe test as adopted, should be used.

It appeared also, that, as stated by Sir H. Davy, the flame would not pass through the meshes at a dull red heat, and that it was necessary, before the flame passed, that the wires of the gauze should be heated to a white heat, this, I had never been able to produce in the previous experiments, and it could only be done by an apparatus similar to that used by which an accelerated motion conld be produced, to raise the temperature to the highest possible degree of heat. In performing each experiment, the motion was at first very slow, and then gradually accelerated; otherwise, the lamp went out, when, however, a white heat was produced, any increase of velocity only added to the intensity of the heat, and had no tendency to put out the flame.

On examining the experiments, it will be seen that, on the 23rd May, none of the experiments passed the flame through the meshes of the gauze; although, the velocity with which the lamp was moved, was 14 feet per second in the 5th experiment, but, as was afterwards ascertained, the experiment was not continued sufficiently long, to produce the requisite temperature of the gauze, though it had traversed 110 feet, at the rate of 9½ miles an hour, and the heat was much beyond what could be produced by any current of air in a mine. In experiment No 1, June 6th, although

the experiment was continued for 116½ seconds in one case, and 114 seconds in another, the distance traversed, being respectively 1173 and 1466 feet, and the average velocities 10 and 13 feet per second. The last experiment, shewing that a velocity of 13 feet per second, kept up for 114 seconds, or while traversing nearly 500 yards, at the rate of about 9 miles an hour, did not cause the flame to pass through the meshes. And that it was only, when a velocity of 15 feet per second, and 19 feet per second, and when the wires were heated to a white heat, that the flame passed. It was always found, that however long, the lamp was immersed in the fire-damp, so long as it was kept standing, or not subjected to a current, that the heat never exceeded that of a dull red heat, a degree of heat much below that at which the flame passed the meshes.

With the Stephenson lamp complete, or with the glass. there was no tendency to pass the flame, the wires, from the diminished quantity of air introduced, could not by any possibility be heated, beyond that of dull redness, so far therefore, as passing the flame, while in a perfect state, this lamp may be said to be a perfectly safe lamp; the glass protects the lamp from the effects of any current of air, or of motion, and the wire cannot be heated, beyond that which the inflammable air, in a state of still combustion, can impart to it. and which as before stated, does not pass the flame. It is only when the glass is broken, and when the lamp becomes, in fact a Davy Lamp, that motion of the air through the gauze, can be attended with danger, and in this state, the No. 2 experiment of June 6th, was made. In this experiment, the flame passed when the velocity was about 14½ feet per second, nearly about the same result of the Davy lamp.

The Jack Lamp is a Davy Lamp with a glass cylinder around the gauze opposite the flame of the lamp, or about half the height of the gauze. The cylinder of gauze of the Davy Lamp being about 6 inches in length, the glass cylinder was about 3 inches, leaving 3 inches of wire cylinder above the glass unprotected. This lamp, as shewn by No. 3 passer, the flame when subjected to motion which produced a white heat to the gauze.

Clanny's Lamp having a cylinder of wire gauze of about 5 inches in length above the glass, also passed the flame when subjected to a white heat; and it is necessary to observe, that a wire gauze of copper passed the flame much more readily than gauze of iron wire, viz., at a velocity of 12½ feet per second when the space traversed was only 88 yards.

The Boty or Belgian Lamp, having also a cylinder of wire gauze above the glass, passed the flame at a velocity of 15 feet per second, and

when subjected to a white heat. The length of the cylinder of wire gauze of this lamp is less than that of the Davy Lamp; but the diameter of the cylinder is larger, and therefore containing as large a quantity of gas within the cylinder, the same result as with the Davy took place.

The Eloin Lamp another Belgian Lamp, is differently constructed, have ing a brass top with a wire gauze cap, but having about two inches of glass, and admitting the air at the bottom; while perfect, it went out with the slightest motion when immersed in the fire-damp. I took off the glass, and substituted wire gauze, and though the cylinder of gauze was only two inches in length, and about two inches in diameter, it contained within that space sufficient gas, when put in rapid motion, as to produce a white heat, and so pass the flame through the gauze. And I tried another lamp No. 6 experiment, June 29th, with a cylinder of gauze $2\frac{1}{2}$ inches in height. and about $1\frac{3}{4}$ inches diameter, which also passed the flame under the same circumstances.

Dnring the prosecution of those experments, it was objected to them that the test was such as could not occur in practice, and that the more correct way of testing the safety of the lamps, would be by subjecting them to rectilinear motion, as more consonant with what was likely to occur in practice—whether the lamp was subjected to a current of air, to a fall from a height—gas being forced upon it by falls of stone, or by blowers—or by persons running away with the lamp in an explosive mixture of gas—no doubt this is correct; but as before explained, I had never been able, under such circumstances, to cause the flame to pass through the gauze. Mr. Thomas John Taylor, however, instituted a set of experiments with similar lamps at the blower of gas at Wallsend; and as these experiments are very valuable as contrasted with mine, I have the permission of that gentleman to embody them in this paper.

EXPERIMENTS

TO TEST

VARIOUS SAFETY LAMPS, TRIED AT WALLSEND COLLIERY, JUNE 28TH, 1853.

Present—Mr. THOMAS J. TAYLOR; Mr. GEORGE CLARK; Mr. THOMAS IRVINE, Engineer of Colliery; the MASTER WASTEMAN; and others.

The gas made use of is direct from the mine, being conveyed in a 4 inch pipe from a barred-up space of about 50 acres at the depth of 140 fathoms, and thence up the C. Pit shaft. It was received by means of a small pipe and stop-cock, into a horizontal wooden box 12 feet long, and 18 inches square inside, with windows at each end, and two windows on the top.

A double groove was made at 3 inches from the bottom of the box, with a sliding platform which moved in it, and on which the lamps were firmly fixed by wedge pieces.

A horizontal wheel was placed outside at each end of the box, the two wheels being connected by a cord which passed round the periphery of both; one cord being outside, and the other inside the box. The inside cord was attached to each end of the moveable platform. A check string was also attached, which allowed a movement in either direction of 11 feet, and prevented the lamps from coming into contact with the ends of the box.

An upright shaft with a handle was attached to one of the wheels, by turning which, various rates of velocity might be communicated at pleasure to the moveable platform, and the lamp upon it, in the interior.

The indications of foulness were at once apparent from the effect on the lamps.

The box was kept cool by admitting fresh air in the intervals of, and sometimes during the experiments, the ends being moveable.

The temperature of the external air was 64°.

The temperature of the gas was 65½°.

The time was measured by a watch with a large second hand pointer, capable of determining accurately a quarter of a second.

Experiment 1*st.*—*With the Common Davy Lamp.*—The lamp, immersed in an inflammable atmosphere, and filled with flame, was moved backwards and forwards, always completing the distance of 11 feet within the second: taking into account the slightly diminished velocity at the commencement and termination of the movement, and the greater velocity in the middle of it, the lamp moved at rates of from 10 to 12 feet per second during the experiment.

The rapid movement increased the brightness of the gas combustion in the interior of the lamp, but had no other effect, until by a still greater increase of speed, the flame was extinguished.

2*nd.*—Repeated the same experiment, after re-lighting the lamp and preparing a new inflammable atmosphere in the box.

The results were as in Experiment 1st.

3*rd.*—Repeated the same experiment with the same results.

4*th.*—Allowed the Davy Lamp to remain in the inflammable atmosphere until the gauze was above a red heat: and then moved it as before with a velocity of 10 to 12 feet per second. The lamp in motion presented a column of light, brighter than in experiments 1, 2, and 3; and by increasing the velocity, was extinguished.

5*th.*—Jerked the Davy Lamp backwards and forwards in the inflammable atmosphere with great velocity, while the gauze was above red heat: at each reversal of the jerk, a flash took place in the interior of the lamp, but no other effect followed, until the lamp was extinguished by the violence of the motion.

In all these experiments the entire lamp was filled with ignited gas, but the flame of the wick continued visible. There can be no question as to the clear character of the experiments.

6*th.*—*Stephenson's Lamp* was extinguished at a much lower velocity than that to which the Davy admitted of being subjected.

7*th.*—*Museler's Lamp,* with a copper chimney inside, was extinguished as in No. 6.

8*th.*—*Clanny's Lamp* (1st Experiment).—Moved backwards and forwards without passing any explosion: but was extinguished before being submitted to as high a velocity as that of the Davy experiments.

9*th.*—*Clanny's Lamp* (2nd trial).—Went out after being moved backwards and forwards several times, though kept full of flame for some time without the glass becoming so heated as might have been expected. Velocity of movement much less than that of the Davy.

10*th.*—*Glover's Lamp* went out at 3rd movement (less velocity than the Davy.

11*th.*—*Glover's Lamp* (2nd trial).—Ditto ditto ditto.

12*th.*—*Eloin Lamp* (a German lamp), Thornton & Co.—Went out on moving a few times, with much less velocity than the Davy.

13*th.*—*Eloin Lamp* (2nd trial.)—Went out as soon as it filled.

14*th.*—*Upton and Robert's Lamp.*—Went out at once in inflammable atmosphere.

THOMAS JOHN TAYLOR.

These experiments prove that whatever motion could be imparted to the lamps moved in a rectilinear direction, had not the effect of producing such a degree of heat as to allow of the passage of the flame through the meshes of the gauze.

The practical result of the whole of these experiments on the different Safety Lamps appear to be as follows:—

1. With the *Davy Lamp,* or with lamps, the insulation of the flame in the inside of the lamp being accomplished by single wire gauze alone, and when the length of the cylinder of gauze is from 2 to 6 inches, the diameter about 2 inches, these lamps are perfectly safe, placed in a still atmosphere of fire-damp. That while so placed the wire becomes of a dull red heat, but such heat does not increase in intensity; and so long as the wires remain in that state of heat, the lamp kept still, and so long as the gauze remains perfect, it will not pass the flame. But it is clear that in practice, such lamps should not be allowed to remain in such an atmosphere; but on the wires becoming red hot. the lamp should be immediately and *carefully* withdrawn.

2. It also results from these experiments, that currents up to ten feet per second of inflammable air, or moving the lamp through an atmosphere of inflammable air at that velocity, has not the effect of increasing the intensity of the heat of the wires so that the flame will pass the meshes; but as we have seen, by these experiments, that an increased velocity under certain circumstances does raise the intensity of the flame within the lamp, so as to heat the wires to a white heat, and so pass the flame; it follows, that it is desirable in practice, that the lamp should be properly shielded from the effect of such a current of air, or from the effect of rapid motion; and that likewise when the lamp is found to

become red hot, it should be withdrawn from the gas or current of inflammable air, as speedily and as carefully as possible.

3. And with respect to *shields* for such lamps and in such cases as the above, it has been shewn that a shield three inches in depth encircling the gauze, leaving two or three inches of the cylinder of gauze exposed, is no preventative of the passage of the flame through the meshes of the gauze, when the velocity of the current of air, or the velocity with which the lamp is moved, is beyond 10 feet per second, or such as to raise the heat of th wires from a dull red to a white heat. Either such lamp must not be subjected as in 2, to such currents or such motion, or the shields should be such as to cover or protect the lamp to such an extent that such currents, does not increase the intensity of the flame of gas within the lamp, so as to make the wires of a white heat, and so pass the flame. It may be observed, that the shield ordinarily used is only a protection to the *flame of the wick of the lamp* from the effect of a current of air, or the motion of the lamp; it is not, however, until the whole of the interior of the lamp becomes filled with flame, when the flame leaves the wick, and when it consists of a combustion of the gases, and not the flame of the wick or combustion of the oil, that the danger commences:— and that a current acting on such combustion raises the heat of the wires. and then, as shewn by the experiments, the ordinary shield of the lamp is of no use in preventing the increase of intensity of heat produced by a current, or motion of the lamp.

4. Stephenson's Lamp, and such lamps where the gauze is entirely shielded or covered by glass, allowing only such a quantity of air to pass into the interior of the lamp as is sufficient for the combustion of the wick or oil of the lamp ; but not such a quantity of air as will keep up the combustion of the gas within the lamp, are perfectly safe lamps, so long as the shield or cover of the gauze remains perfect. As such lamps are never subjected to a greater heat in the interior of the lamp, than that given to them by the flame of the wick, or by the elongated flame produced by the admission of the inflammable air, previous to the air being in an explosive state ; the intensity of the heat cannot be raised by any current which can pass through the diminished number of apertures into the interior of the lamp so as to make it unsafe. The principle of such lamps being, that the quantity of air admitted is only sufficient for the combustion of the wick or oil, and not sufficient to keep up the combustion of the gases when the air becomes in an explosive state. When, therefore, the air of the mine becomes explosive, the combustion leaves the wick, and it would then produce a combustion of the gases ; and as in the Davy Lamp the effect of a current of air acting upon such combustion, increases the intensity of the flame, and raises the heat of the

wires from a red to a white heat, and so allow the flame to pass. The Stephenson Lamp, on the contrary will not keep up a combustion of the gases, the flame within the lamp being extinguished for the want of a sufficient quantity of air to support such a combustion of the gases.

5. It has been urged against the Davy Lamp, and those lamps of single gauze insulation without shields, that the dust of the mine, or their being in in a dirty state, renders them unsafe. The experiment No. 2, June 29th, shews that it is difficult to pass the flame through the meshes by throwing coal dust upon the gauze when the wires are red hot, or by spilling oil upon it in that state ; but it need scarcely be added, that lamps should not be permitted to be subjected to any such tests—when red hot, they should, as stated in 2, be immediately removed—and the lamps should be subjected to the requisite examination to ensure their always being in a clean and perfect state.

6. It has also been objected to the Davy Lamp, or lamps insulated with wire gauze, that they do not afford the requisite degree of illuminating power to allow the workmen to pursue their avocations, and consequently insulation by glass or talc has been resorted to. Without adverting here to the degree of safety of such insulating substances, the experiments on such lamps shew that if the air is admitted freely into the interior of such lamps by the use of wire gauze tops, (such as in the Clanny Lamp and the Museler Lamp), and where, consequently, the quantity of air admitted into the interior of the lamp is such as to support the combustion of the gases; such lamps, when subjected to currents or motion under the circumstances shewn in the experiments, pass the flame. It becomes, therefore, apparent that such lamps present twofold danger, viz., the risk of breakage of the glass, and the danger arising from the intensity of the combustion of the gases within the lamp when subjected to a current of inflammable air or motion ; and it would appear that the remedy for the latter would be to so construct the lamp that such a combustion of the gases cannot exist in the interior of the lamp to produce such an effect ; this can easily be done by diminishing the quantity of air admitted into the interior of the lamp, and which indeed is done in some of the lamps.

7. With reference to the use of glass or talc as insulating substances, the fact of the employment of such numbers of lamps as those of Clanny, and the Museler Lamp, every day, without any or so few accidents from the cracking or breaking of the glass, would prove that such an insulating substance as glass properly annealed, and the lamp properly constructed, is a safe lamp. The Clanny Lamp, in these experiments, when the wire was in a state of nearly white heat had water thrown upon the glass by a jet thrown into the box, the water had the effect of cracking the glass, but the flame did not pass. The glass of these lamps are, however, liable to crack from the expansion when subjected to great heat, where proper care has not been taken to allow of the

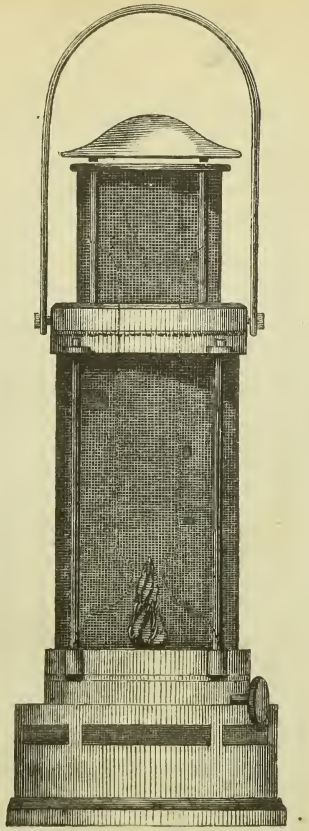
free expansion of the glass in the construction of the lamp : but this is easily remedied.

8. Lamps have been produced, such as Dr. Glover's, with two cylinders of glass, the air being admitted into the interior of the lamp, by passing between the cylinders, for the purpose of keeping the glasses cool—and some lamps with water between the glasses. No doubt double glasses adds to the security, but if such lamps have an unprotected wire gauze top, the effect of the heat of the combustion of the gases is much beyond the cooling effect of any air passing betwten the glasses, and the intensity of such heat, besides adding to the risk by the the flame passing the gauze, also tends to heat and crack the glass. These lamps do not necessarily require wire gauze tops, as brass or copper tops, such as are used in the Eloin Lamp, may be adopted. Double wire gauze tops such as T. Y. Hall's and Dr. Fife's Lamps, have been used, counteracting to a certain degree, the effect of interior combustion, as the outer cylinder of gauze, not being subjected to the direct action of the flame, remains free from injury.

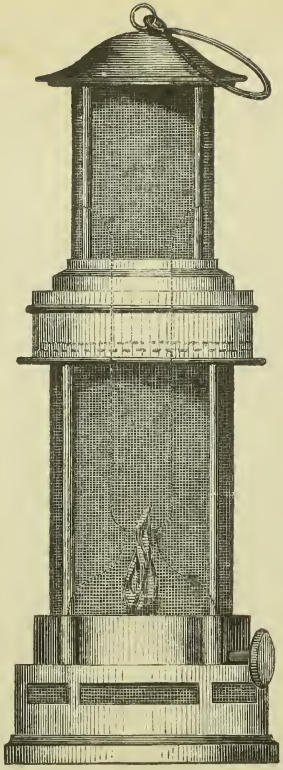
9. It would appear as a summary of all these results, *that if the Davy Lamp is used, or lamps, the insulation of which is accomplished, by cylinders of wire gauze alone,* proper precautions should be enforced, for their careful removal when the internal combustion of the gases takes place, or when the wires of the gauze becomes red hot, as the margin of danger is between the wires being at a red, and becoming of a white heat. Or that shields of glass or other materials should be used in such lamps, to so diminish the quantity of air or gas admitted into the interior of the lamp, that active combustion of the gases cannot exist, so as to raise the heat of the wires from a red to a white heat :—taking care of course, that the lamp is supplied the requisite quantity of air, when the atmosphere of the mine is at, or just below, the inflammable point, to support the combustion of the wick or oil. With such a lamp, when the mine becomes explosive, the gas will explode in the lamp, combustion of the gases will commence, and the flame will leave the wick ; but as there is not a sufficient quantity of air admitted to keep up a continuous combustion of the gases, the flame will be extinguished ; and consequently, the wires can never become of a white heat or the lamp become dangerous.

And, *that in all lamps where glass is used as the insulating medium,* the admission of air into the interior of such lamps, should be so diminished, as that active combustion of the gases cannot take place within the lamp ; and more particularly, that tops of single wire gauze unprotected, and therefore liable in explosive mixtures of gas, to the objections heretofore stated, should be avoided.

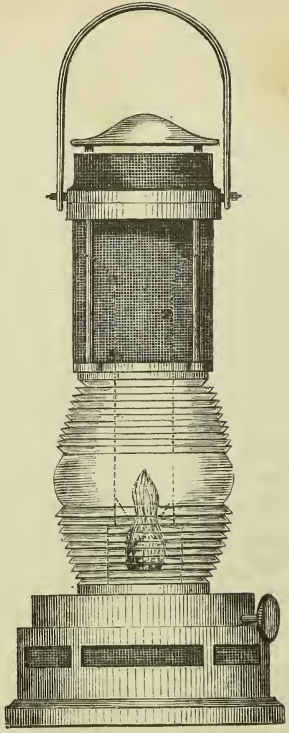
NICHOLAS WOOD.



No. 1.—PATENT LAMP.



No. 2.—LAMP.



No. 3.—DIOPTRIC LENS LAMP.

MR. T. Y. HALL'S PATENT SAFETY LAMPS.

Gauze, 1,296 *Meshes per square inch.*

SAFETY LAMPS.

A PAPER READ AT THE MONTHLY MEETING OF THE NORTHERN INSTITUTE OF MINING ENGINEERS, HELD ON FRIDAY, THE 5TH OF AUGUST, 1853, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE.

BY THOMAS YOUNG HALL,

(ELDON SQUARE, NEWCASTLE-UPON-TYNE.)

My attention having been directed towards the Improvement of what are denominated Safety Lamps, to be used in mining operations, I have endeavoured to accomplish the following objects, namely :—

First.—To obtain a more brilliant light than is afforded by any of the existing lamps.

Second.—To effect greater security against explosions.

The course pursued to attain those objects, as well as the manner in which they have been practically realised, admits of very brief explanation.

By introducing certain simple modifications in the construction of Upton and Roberts' lamp, I propose to effect various changes, which will be attended with highly important and beneficial results.

It may be observed, that in Upton and Roberts' lamp the atmospheric air enters through a number of holes formed in the rim of the oil-pan, and passes through a vault, having an aperture in the centre of the dome, to the flame, which is protected by a cylinder of gauze and an external cylinder of glass,—the gauze cylinder being about an inch and three-quarters in diameter, and the glass about two inches.

The motives by which I am actuated in pursuing this course are

entirely of a public nature; my object being solely to promote the welfare of that great interest which is the main-spring of the prosperity of the northern counties, and at the same time to render a service to the cause of humanity, by making an additional provision for the safety of those who subsist by under-ground occupations.

By the use of my lamp, the miner will be placed in the enjoyment of a flood of light equally as cheap and much more brilliant than that which he before possessed, and will be enabled to follow his occupation with greater ease, comfort, and cheerfulness, securely guarded against those fearful explosions which have hitherto spread desolation through the homes of thousands, but which, I trust I have, under Divine Providence, at length ascertained the means of wholly, hereafter, preventing. I refer for a description of the properties and advantages of the lamp to the printed paper which accompanies this address, and respectfully entreat that, not out of regard for myself, but for the sake of that great object which it is designed to attain, it may undergo a candid scrutiny, and have its pretensions to confidence determined by the dictates of truth and justice, and by these alone.

In introducing to public notice my improved Safety Lamp for the use of miners engaged in the working of coal-pits, either in Great Britain or in other parts of the world, I am aware that I shall have to contend with those obstacles to its immediate and general adoption which, in all similar cases, are presented by the prejudices of those who do not wish to see old systems or practices broken in upon, and the reluctance which many feel to adopt any innovation upon the existing order of things, or even to investigate the merits of any discovery that may seem to threaten the overthrow of what they have been accustomed to regard as perfect and unalterable. I am encouraged, however, to persevere in my efforts to obtain for my invention that fair consideration which I feel to be due to it, from the importance of the subject with which it is connected—and, I would fain hope, to bring it, eventually, into extensive, if not universal application,—by the approbation which some of the most eminent professional men engaged in the superintendence of the largest colliery establishments in the great coal-fields of Durham and Northumberland have been pleased to bestow upon my labours, and the highly favourable opinions they have expressed as to its probable utility, alike as a means of economising the pecuniary expenditure inevitable to the prosecution of mining enter-

prise, and of protecting the lives of the numerous industrial population engaged in its operations.

In my lamp, by placing a cylinder of glass within the gauze, resting upon the dome of the air-vault, and closely surrounding the central aperture, the air, after it enters, instead of being (as is the case in all other lamps) dispersed throughout the lamp, is thrown underneath and concentrated directly upon the flame, and greater brilliancy of light is the result. This constitutes the principal improvement in my lamp, and is the most important that has been introduced since the original invention of Sir Humphrey Davy.

Then, with respect to the admission of external air to feed the flame, that is effected in my lamp by means of perforations through a portion of the dome of the air-vault, and not through the side of the brass rim of the oil-pan, as in the lamp of Upton and Roberts.

There is also a modification introduced into my lamp with regard to the gauze, which is so placed as to entirely surround the air-vault, the perforated portion of the dome of which is then between the gauze cylinder and the inner glass tube. The space between these cylinders is divided into two portions by a rim about four inches from the bottom, extending from the inner glass tube to the gauze. That portion of the air which enters below this rim is guided through the holes in the dome of the air-vault to the central aperture, whence it passes directly upon the flame. This principle forms another important improvement in the construction of my lamp.

In the division of the lamp below this rim or stopper are comprised the light chamber and the ventilating part; and in order as well to protect the gauze in this part as to facilitate the removal of dust or oil that might accumulate in the meshes so as to obscure the light, about four inches of the bottom part of it is enclosed between two glass cylinders, leaving a small portion of open double gauze between the top of the glass casing and the edge of the rim stopper. In consequence of this arrangement, the external air is admitted through the gauze at that part where it is most necessary to avoid danger. A sufficient quantity of air to feed the flame and give a brilliant light will enter through the open portion of the gauze below this rim, descend between the cylinder and the glass tube, and pass through the air-vault to the flame in the manner above described.

One important advantage obtained by bringing the external air down between the transparent cylinder and tube is, that the current keeps the

inner tube and the intermediate gauze cylinder cool, or, at any rate, much cooler than by any other system. This arrangement with the inner tube is peculiar to the lamp of my invention, and constitutes one of its most important features; for it not only increases the light, but adds considerably to the safety of the lamp.

Other advantages are also obtained by encasing the gauze of the light chamber. A much finer gauze, of iron, copper, or platina wire, in its natural state, for instance, might be used for safety-lamps, with or without one of the glass protecting cylinders, and not be so liable to rust, and greater brilliancy of light obtained, even with 1,296 holes per square inch in the mesh, which is 512 more than in the Davy or other lamps; and this sufficiently strong for all purposes of safety.

Further, should the glass, inside or outside, become dirty, the meshes of the wire would remain perfectly open and clean, and the dirt or coal-dust could be wiped off the glass at any time with the utmost facility, and the full power of the light maintained undiminished by causes which not only obscure the light in the "Davy" and other lamps having an external or internal glass cylinder, but increase the danger arising from explosion. The large quantities of smoke in other lamps is also very objectionable. Accumulations of coal-dust or oil in the meshes of the gauze cannot take place under any circumstances from the manner in which the gauze in the light chamber of my lamp is protected; whereas, should an accident occur to break the glass casing, the lamp would stlll be safer than before, on account of the inner tube protecting the flame inside so completely.

The upper portion of the lamp, above the rim or stopper, may be denominated the "safety part." It is formed with double or treble gauze, or gauze sheathed inside with perforated copper, except for about a quarter of an inch next to the rim-stopper, which is also double. The external air will enter through this part, and, passing upwards, in some measure subdue the heat that might otherwise accumulate there.

By the introduction of the inner glass tube, so as to concentrate the air upon the flame, when the wick is kept at the proper height, the flame will be of the proper length, and the smoke and gas that enters with the air may be entirely consumed, and all danger of exploding the gas outside completely obviated; for, in an explosive mixture of gases, my lamp will become extinguished at the proper point; while, from its improved mode of ventilation, it will burn for a much longer period than will ever be considered necessary in such a case, showing indications of danger at the

flame, so as to give warning, and afford sufficient opportunity for the workmen to retire until the explosive mixture has been dispersed.

While contradictory evidence is given on the subject of the Davy lamp, it may be necessary to refer to the facts relating to the conditions under which fire damp manifests itself in mines, contained in the valuable paper by Thomas John Taylor, Esq., published in the Appendix to the South Shields Report, and now reprinted with that report by the parliamentary committee, which offers the most complete refutation possible of the conclusion of the committee on this subject.*

It may be remarked that the superior ventilation of my lamp enables me to use an Argand, a solar burner, or any other that may be thought desirable; and I may state that I am at present engaged in making experiments with wicks manufactured differently from those in common use, with which my lamps burn very well, but which will no doubt be superseded by others. These improved wicks are extremely simple; and though short in length as compared with the common wick, they are expected to burn longer, with a steady, clear flame, producing no smoke, for ten or twelve hours, without requiring that attention to pricking and snuffing which are absolutely necessary with the ordinary lamp and common wick; in short, to do away with the inconvenient and complicated process of pricking and snuffing altogether, and, by moving a screw connected with the wick, increasing or diminishing the flame at pleasure, as well as economising the oil where a larger light than a pit-candle is not wanted.

There are many advantages besides those above enumerated, which my lamp possesses over those in ordinary use, but they are so obvious that it is unnecessary to enter upon any lengthened description of them in this paper.

It may be observed, however, that the gauze encased in these glass cylinders not only assists to guide the air into the vault, but also completely steadies the flame in the tube, and protects it from the transparent gauze cylinder. The importance of this improvement was particularly observable in the experiments at Killingworth by Mr. N. Wood, Mr. George Elliott, Mr. Wailes, Mr. John R. Liddell, and myself; for even when my lamp was moving in a circle at the end of a horizontal bar, revolving at the rate of from twelve to fifteen feet per second, the flame still continued steady and perpendicular, not being in the least degree affected.

* Mr. Taylor has recently read a very interesting paper on this subject to the Society of Mining Engineers.

There is this additional advantage in my lamp over the Davy or any other lamp with gauze unprotected by glass—namely, that the workmen cannot light their pipes by sucking the flame through the wires.

If it should be thought desirable to form the lamp wholly or in part of glass, then the principle upon which my lamp is constructed is, in my opinion, the best that can be adopted, both for the safety of the miner and for producing a light sufficient for *all* mining purposes.

I will now proceed to give a description of another lamp on the same principle, as far as ventilation goes, but with an improved mode of applying the oil, gas, or candles, rendering it, in that respect, self-acting. The plan, if with oil, is to transfer the oil-pan from the bottom to nearly the top of the lamp, and instead to introduce a bullion of peculiarly prepared glass at the bottom. In that case, one or more of the pillars would be made hollow, and the oil would be let off gently by means of a spiral screw, and would descend into a well formed in the bullion to suit the apparatus for the improved wick, where the oil would be a little cooler. The bullion, being a non-conductor, would not become so heated, and its being partly transparent would be another great advantage, because the level at which the oil stands, or ought to stand, could at once be seen. A still further improvement might be effected by making the sides of the oil-pan at the top of the lamp of a rim of glass, and partly to rest the pan upon any non-conducting substance, which will prevent it becoming heated. The quantity of oil consumed in one day, while the lamp will be locked, is so small that the oil-pans, with the bullion at the bottom, will neither add to the weight of the lamp nor cause inconvenience in the use of it. The ring or handle at the top, with the pillars, could easily be made to lock the lamp.

The improvements introduced in the construction of my lamp enable me (if necessary,) to use the gas from a pit-blower instead of oil; the gas can be conveyed into the burner of the lamp at any part of the pit, through pipes adapted to the purpose. In the Emma Pit at Townley Colliery, near Ryton, a large blower in one of the seams of coal discharges a considerable quantity of gas, which, instead of being carried away in the return, and over the furnace, as is usual, is usefully and economically employed in lighting up the shaft, the whole of the pit-buildings at the top, and a portion of the workings of the mine below. The gas is discharged into a

pipe, along which it is conveyed into the dip-workings, which are filled with water: for a distance of about two hundred yards it passes through the water confined in these workings, and makes its escape at a point forty feet above the level at which it entered the water into a dry drift, with a close dam tapped by means of a pipe, with a regulating-cock outside. This pipe is continued to the bottom of the shaft, and thence into the main working-ways, where lights are required. These may be either fixed or made moveable by means of a flexible pipe attached to my lamp; and, where it is desirable to have a small bright flame, the gas might be passed through a sponge saturated with naphtha, placed in either of the pans at the top and bottom of my lamp, or in both of them. The whole of the main drifts, as well as the smaller workings, may be thus lighted with gas, under lock; and, as it has been stated that blowers sometimes come off by the falling in of goaves,—thus forcing the gas into the main drifts, where it is likely to explode at naked lights, which are generally used there, without any advantage over the closed light,—the whole of the danger arising from that source is completely obviated by the use of my lamp, which, in fact, renders naked lights quite unnecessary when gas is considered dangerous in a pit.

It is my intention to extend the system into the more dangerous parts of our Townley Colliery, according to the supply of gas and economy in its application. The pipe from the bottom of the shaft is continued upwards to another working seam, where the gas is applied in the same way as in the seam below. The same pipe is still further extended to the top of the pit, where it enters a gasometer, in which is collected all the gas from the blower alluded to not used in the mine during the course of the day; and this gas is applied to give light to the workmen not only at the bottom, but at the top of the pit, also lighting up engine-houses, workshops, offices, &c., for which it is found to be more than sufficient. If the superabundant gas be passed into the upcast shaft, and lighted up in the heated tubes, an increased ventilation will be created, which, upon the same plan, may be further assisted by the gas emanating from the retorts used in making coke from the refuse small coal, either at the top or bottom of the mine. The upcast will thus be relieved of the immense quantity of smoke usually arising from the furnace, which I have seen with heat and hot flame, both in this and other countries, set fire to the coal; even so at the present time, which causes immense loss of property to the owners and great risk to the lives of those employed in the mines at the time. It is not improbable that the small coal and natural gas being thus applied, will

altogether supersede the furnace and its objectionable smoke. Apparatus of the sort proposed may be seen in operation at the Emma Pit, at Townley Colliery, near Ryton, by applying to Mr. T. Y. Hall, Eldon Square, Newcastle. The analysis of this gas, which is very pure, Mr. R. Simpson, the agent at the colliery, will give you at a future meeting. At the top of the pit he causes it to pass through a sponge saturated with naphtha, which increases the brilliancy of the light where it is desirable. This is the same gas with which Mr. G. C. Greenwell made his experiments, both with and without naphtha, in trying to explode gas at a heated plate and iron-wire safety-gauze, the details of which were given in the paper that he read at our June meeting, and which he kindly promised to repeat and extend, at the request of our President, after obtaining an analysis of the gas. (See p. 16.)

In order to obtain the necessary quantity of air, there is placed at the bottom of almost every mine a large furnace, which is supplied with fresh coals every few minutes, to create a large flame, over which passes, in most cases, all the air and gas in the pit, except when the air is very much charged with gas, and then it is carried over a *dumb drift* generally above the furnace, which takes the air largely charged with gas into the shaft. To obviate this danger, and make any pit quite secure where nothing but proper safety lamps are used, all the air and gas might go through proper wire gauze, so that the gas, if accidentally ignited at the furnace, would not pass back into the mine through the wire-gauze pipes.*

So many differently constructed lamps are in existence that much uncertainty, inconvenience, and doubt have arisen, and still prevail, with regard to the safety of all or any of them, including even the first, which, in my opinion, was the *best* lamp ever yet invented, having been considerably and more generally used in this country than any other for about forty years, and for many years, in numerous instances, to the knowledge of many of you as well as myself, in this and other country coal districts, very severely tested. Nearly two dozen different kinds of lamps, manufactured in this and other countries, have been exhibited at various times, and descriptive drawings of which are given in a recently-published work, by our eminent fellow-townsman Dr. Richard-

* If the suggestion be not improper, I would propose that a committee of members of this Institute should be appointed to investigate the evidence now given before the committee of the House of Commons on the subject of ventilation, so as to make some improvement, by a short plain report, if possible, upon the plans which may be adopted under the sanction of Parliament.

son, entitled "Chemical Technology." They were tested lately at Killingworth, at the expense of our respected president, Mr. N. Wood, who has devoted immense time and trouble, not only to those experiments on safety lamps, which were conducted by the aid of an ingenious and expensive apparatus, but also to other experiments, scarcely less important than these, on the different modes of ventilating coal mines, by furnace, steam jet, and the pumping system, and to whom the coal trade, the public, the members of this Institute, and last, not least, the Government itself, and particularly, in my opinion, the inspectors appointed by it, are under the deepest obligations. Mr. Wood's apparatus was not adapted to ascertain the proportions in which the air and gas were admitted; but in order to ascertain these points correctly, which are very important, I am, with the assistance of Mr. P. S. Reid, of Pelton Colliery, preparing an apparatus at Townley Colliery, where we have a blower of gas very pure and well adapted for the purpose; the result of which I shall lay before you at a future meeting, along with other important facts. Nearly the whole of these two dozen lamps had glass exposed without being covered with a proper safety gauze; and all of them were, in my opinion, proved to become defective in some way or other, the contest of merit being limited to four—namely, that of Upton and Roberts, Stephenson, or the "Geordy," Sir Humphrey Davy's, and my own, all of which have an exterior covering of safety gauze. There were two or three others with exterior gauze, but they did not stand the severe test to which they were submitted, and which was borne by the four above mentioned. The first two—Stephenson's and Sir Humphrey Davy's—bore a severe test before they passed the flame, the gauze having to be, not in a *red*, but in a white heat, for a considerable time before they did so. The "Geordy," having a glass cylinder within the gauze, did not in that state pass the flame, but the light was extinguished very rapidly: when, however, the glass was removed, and a trial made without it, the "Geordy" passed the flame quicker than the Davy. Upton and Roberts' lamp collected the smoke and soot so rapidly inside the whole lamp, that the flame lost its illuminating power, and was nearly out, before it came amongst the gas. My lamp, however, when properly constructed and used, will stand a much severer test than any of the others—will, in short, never come into a red heat, and, consequently, cannot pass the flame. *There* are two or three glass lamps—one by our highly-talented townsman, Dr. Glover, which was tried, and which went out quickly, but, as Mr. Wood remarked, having only a single gauze upon the *glass* cylinders, it was in that part a Davy

lamp, and with the like liability in that respect. Another lamp, by Dr. Fife of this town, could, as I have remarked to him, by the adoption of my principle, be made as good a glass lamp as any. The like may be said of Eloin's and Muesler's.

If, then, there exist doubts in respect to the safety of all or any of the lamps that have been heretofore invented, either in this or any other country, it behoves our Government, and Government inspectors, the miners themselves, and more particularly the owners of collieries and the members of this Institute, to investigate the subject fully, and, after due deliberation, to fix upon one lamp, either mine or any other, which may be taken to be the safest and the best, giving the most light to the miner, and affording him the greatest security from explosions. Having fixed upon such a lamp, its general use ought to be enforced as far as practicable. Should my lamps come into general use, I would consider it desirable, in order to get them perfectly constructed and well locked, and at the cheapest rate, to regulate the manufacture of them by law. There is no doubt in my mind that they could be manufactured at as cheap a rate per thousand as any of the lamps now in use, and not heavier than the Davy or Stephenson, which are the lightest. In order that no impediment should prevent their general adoption, so far as I am concerned, although I have a patent, no Patent Right Tax should be suffered to interfere, or be imposed at all, unless the amount collected went to a Government Bank, there to accumulate, and then be distributed among such miners or their families as may be deserving of such aid. Out of such a fund premiums might occasionally be given to pitmen or miners for mining education and good conduct, and to those who were the most careful and kept their lamps (for a considerable time) in the safest and best working condition.

"The following experiments, on the lighting powers of various lamps, were tried with a Photometer at Wallsend, on 30th October, 1849. Present, Mr. Parish with a safety lamp, Messrs. George Clark, James Easton, and Thomas John Taylor.

STANDARD, A WAX CANDLE OF SIX TO THE POUND.

	Number of Lamps required to equal Wax Candle Standard.		
	On 30th Oct.	On a previous day.	Average result.
1. Davy lamp with gauze . . .	9	7	8
2. Stephenson's lamp	17	20	18½
3. Upton and Roberts' lamp . .	25	24	24½

4. Dr. Clanny's lamp (glass) . .	$3\frac{5}{8}$ . .	5 . .	$4\frac{1}{4}$*
5. Muesler's lamp (glass) . . .	$3\frac{1}{16}$ . .	4 . .	$3\frac{1}{2}$
6. Greener's lamp (talc) . . .	4 . .	$3\frac{1}{4}$ . .	$3\frac{1}{2}$
7. Mr. Parish's lamp with gauze .	$2\frac{3}{4}$ . .	— . .	$2\frac{3}{4}$
8. Davy lamp flame without guaze	$2\frac{1}{2}$ . .	$2\frac{1}{2}$ . .	$2\frac{1}{2}$
9. Common pit candles (30 to the pound)	2 . .	2 . .	2

"As two pit candles are equal to the standard wax candle, by dividing he results by two, we obtain the lighting powers of the various lamps comparatively with those of a pit candle of thirty to the pound. For example, the light of a common pit candle is equal to that of 8÷2=4 Davy lamps.

"T. John Taylor."

It appears, from the foregoing statement, that the proportion of light to a common pit candle of thirty to the pound, is in

Upton and Roberts' Lamp . . .	$12\frac{1}{4}$	to	1
Stephenson's ditto . . .	$9\frac{1}{4}$	to	1
Davy's ditto . . .	4	to	1

The result of experiments made with these lamps, on Tuesday the 2nd August, 1853, at the same place, by Mr. Thos. John Taylor, Mr. Clark, Mr. Reid, Mr. Laws, and myself, was about the same as the above.

I consider my lamp will give a light equal to the common pit candle; which may be considered sufficient for all practical purposes, and is the point that many scientific and practical men have unsuccessfully attempted to arrive at, during the period that has elapsed since the days of the great originator of safety lamps, whose name the mining population of this district, and humanity at large, must ever hold in grateful and reverential remembrance, with the names of Stephenson and Clanny.

I cannot conclude without stating, that I have been kindly allowed, through the kindness of the widow of the late Rev. John Hodgson, who was rector of Heworth at the time of the large disastrous pit explosion at

* "In any lamp with less than 784 holes to the square-inch in the mesh, the light would be so reduced that no pitman would attempt to work with it."—*Newcastle Journal*, 7th April, 1849—Article on the Clanny lamp.

Felling Colliery in the year 1812, to have access to the whole of the original correspondence between that gentleman, Mr. Buddle, and Sir Humphrey Davy, from the first day the latter directed his attention towards inventing a safety lamp. The reverend gentleman, as well as my late colliery partner and friend, Mr. J. Buddle, I found, very much to their honour, assisted Sir Humphrey to the utmost of their power, in pursuing his investigation and bringing the result before the public.

Since I addressed the members of the Institute, in July, on the subject of Safety Lamps, and described the experiments I had made in pursuance of the provisional specification I had several months before lodged in the Patent Office, for the purpose of obtaining a greater quantity of light and other advantages, I have, by a series of experiments and other modifications, fully succeeded in obtaining the desired result. My attention has been directed to the obtaining of increased safety and cleanliness, as well as a greater amount of illuminating power. That I have succeeded on the first point, will, I think, be readily admitted. The provision I have made in the lamp for the rapid consumption of the smoke it generates, ensures the second object; and for the attainment of the third—namely, increase of light,—I have adopted an oval lamp, with one large and powerful plano-convex lens in front of the flame, and the flame itself I place in the focal centre of a parabolic reflector. The rays of light impinging upon it are condensed by the lens, illuminating very powerfully a considerable space. And it has since struck me that a still further improvement may be made in this respect, by surrounding the flame with a polygon lens, the flame in the lamp being secured by gauze. This, I am satisfied, would diffuse a very strong light in all directions required. The lens I propose to adopt is the *dioptric* lens of M. Fresnell. I intend very shortly to have a lamp made on this principle; and which I will submit to the inspection of the members of the Institute at the earliest possible opportunity. This lamp, although of a different shape, will be neither larger, longer, nor heavier than my present safety lamp.

I have already tried the principle, to a certain extent, with the wire gauze, now commonly in use, the meshes of which are of such a size as to admit 784 in the square inch. I have not yet procured the gauze that I proposed to use with my lamps, and containing 1,000 or more perforations

in the same space; but I have found one containing 1,296 (which I formerly referred to in regard to another lamp) to answer well, and to emit a beautiful light when used in the lamps which I have completed; and it is a remarkable fact, that iron wire gauze, platina-wire gauze, or even copper-wire gauze, containing from 1,000 to 1,200 perforations in the square inch, or upwards, and so encased in glass, may be considered sufficiently strong, and will give a light adequate to all purposes, and still make the lamp both stronger and safer than with the common gauze heretofore used with 784 holes per square inch.

The wire gauze which I propose to use contains about 1,200 holes per square inch, which, if made of iron, will be sufficiently strong and perfectly safe; and the lamp little or no more costly than the ordinary guaze lamps; or, if a small portion be constructed of platina, for the dome part, at 35s. per ounce, would not, from its trifling weight, exceed the price at which glass lamps are now selling. The only portion I constructed of platina was the small dome over the flame, for the inner glass tube, before I had ascertained, by experiment, the size and form of glass suitable for the same purpose — the consumption of smoke. A dome made of platina, with 6,400 holes to the square inch, for the glass tube to rest upon, did not add more than 2s. to the entire cost. Besides, my lamp, whether the gauze were made from iron or from platina, would, from the neutralisation of dust, or smoke, or flame, seldom require repair; and, in fact, if well made, would last for a lifetime. As to the amount of light it emits, some conception of this may be formed from the circumstance of my having, in experimenting with a brilliant flame, and a gauze containing 6,400 holes, and another the extraordinary number of 10,000 holes, obtained treble the light derived from the Davy, with or without encasing it in glass cylinders.

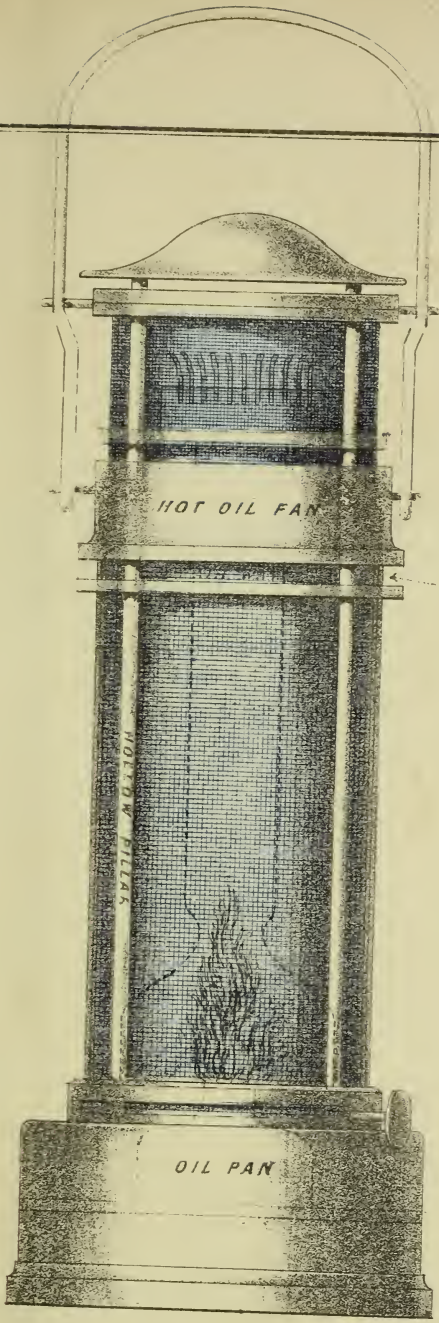
P.S.—I consider that my principle of ventilating safety-lamps may be applied to other lamps of any size, to supersede the stove or grate in rooms, in which, with this mode of ventilation, gas or oil, or any other sources of illumination might be used, not only warming and lighting the room, but filling it with pure air at an even temperature. It is admitted by all that pure air is essential to the preservation of health; and the Faculty unanimously ascribe consumption, and other equally fatal diseases, to the vitiation of this element. An eminent author, fully alive to this evil, calls a close stove a red-hot demon. Why then should life be sacri-

ficed and money expended—as in the case of the two Houses of Parliament —to no purpose, while the remedy is here placed within the reach of all? The tables of mortality exhibit, in a remarkable degree, the greater longevity enjoyed by those who not only are of temperate habits, but who, from combined circumstances, can enjoy the inexpressible blessings of pure air in well-ventilated apartments; and when we reflect that one-half the population die before reaching the age of twenty-one, the most inconsiderate must admit the necessity of pure air and better ventilation. The Society of Friends, whose habits are uniformly temperate, and who are feelingly alive to the necessity of pure air and cleanliness in dwellings and person,—their term of life averages fifty-one years, whilst the average mortality of the rest of the world gives only thirty-three years to each individual, showing a difference of eighteen years' longer enjoyment of life in favour of that sect over every other; and as every life has a certain value, pure air, obtained by better modes of ventilation, with temperate habits, would add permanently one-third, or fifty per cent., to the human family throughout the world, and life would be prolonged at a time when the thinking and productive faculties are in their fullest vigour.

ANALYSES OF GASES IN THE SEVERAL COLLIERIES UNDERMENTIONED, WITH THE NAMES OF THE PARTIES BY WHOM THE ANALYSES WERE MADE.

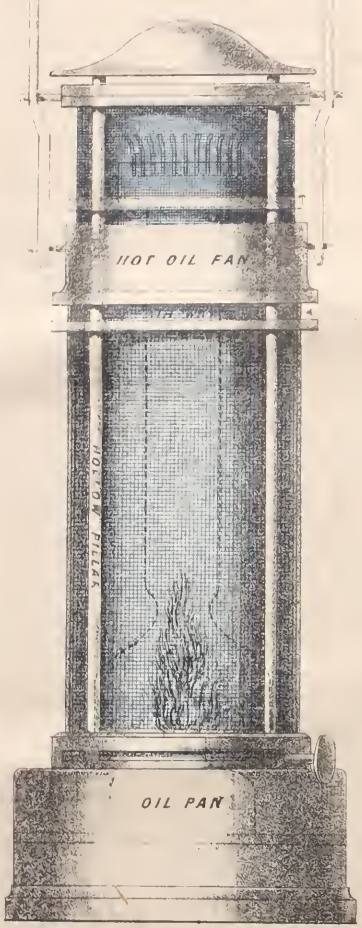
	Stella.	Emma Pit Townley 4th Seam.	Whitefield.	Wallsend Bensham Seam.	Jarrow. Bensham Seam.	Jarrow. Low Main.	Hebburn Bersham Seam.	Killingworth.		Gateshead.	Saarbruch. Willesweik	Saarbruch. Gernard.
Carburetted Hydrogen	..	56.17	..	77.5	83.1	79.7	91 8	82.50	66.30	94 20	87.43	79.84
Nitrogen	..	4.68	..	21.1	14.2	12.3	6.7	16.50	6·32	4 50	..	..
Oxygen.....	..	..	..	..	0.6	3.0	0.9	1.00	..	1.30	..	..
Carbonic Acid..	..	6.00	..	1.3	2.1	2 0	0.7	..	4.03	..	4.30	3.90
Olefiant Gas ..	..	..	..	..	..	..	..	..	..	..	6.05	1.90
Atmospheric Air	..	33.15	..	..	..	..	..	..	23.35	..	2.22	14.36
		100.0		99.9	100 0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
		Richardson.			Playfair.			Graham.	Richardson	Graham.	Bischoff.	

PRINTED BY J. WODDERSPOON, 16 AND 17, PORTUGAL STREET, LINCOLN'S INN FIELDS.



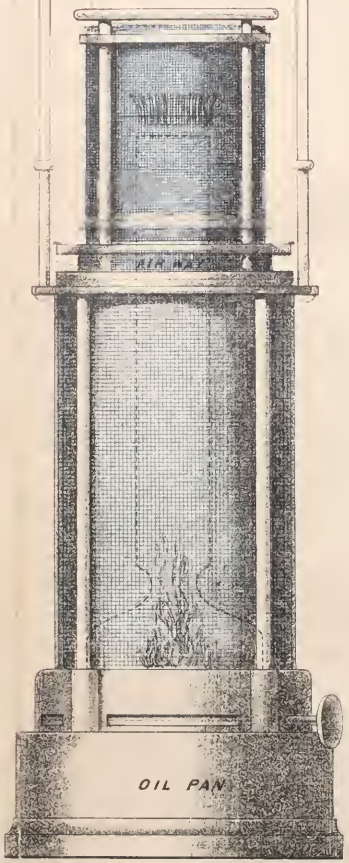
Nº 1 PATENT LAMP.

MR T. Y. HALL

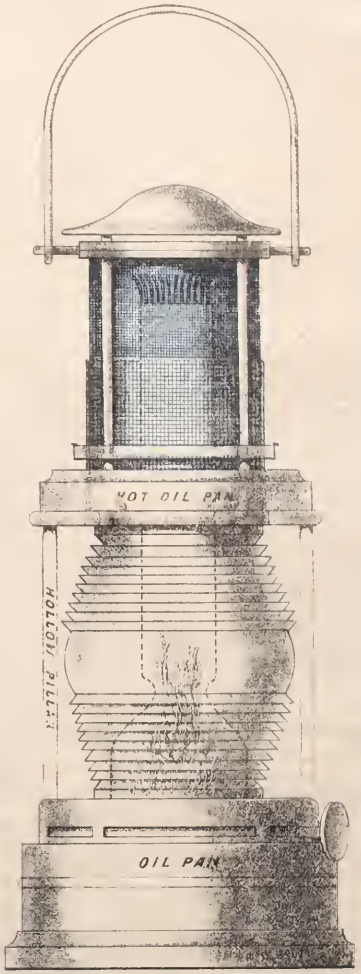


$\frac{1}{16}$ of an Inch

No 1 PATENT LAMP.



No 2 LAMP



No 3 DIOPTRIC LENS LAMP.

Mr T. Y. HALL'S PATENT SAFETY LAMPS.

Nearly Full Size with Gauze 1296 Meshes per Square Inch

Lambert's Lith. Newcastle

SHORT DESCRIPTION

OF

Mr. T. Y. Hall's Patent Safety Lamps.

The principal improvements in these Lamps consist of arrangements for obtaining superior combustion, the consumption of smoke, and an increase of light, with complete protection from explosions of gas, so destructive to human life in coal mining operations. These objects are effected by the admission into the lamp of the external air necessary to support combustion through apertures in a portion of the circumference of a cylinder of gauze about one-sixteenth of an inch in depth, and two inches below the top of the Lamp, and by conducting it downwards between a sheathing of glass surrounding the lower portion of the gauze and an inner tube or chimney, into a chamber or vault in the oil-pan, having a central aperture, through which the cool air returns upwards, and is directed against the flame within the tube or chimney, which assists in consuming the smoke and guides the heated air into the upper chamber, which is formed by a stopper extending from a brass rim above the air-way to the inner tube, whence it makes its exit in all directions through double or treble gauze with perfect safety from explosion. The cool air may also be admitted at the bottom of the lamp; its admission in either case being regulated by means of a screw plate or moveable slides. In consequence of the admission of the air being thus accurately regulated to a sufficiency for to feed the flame and no more, the gas that enters when the Lamp is in an explosive mixture is so small in quantity, and so extensively diffused through the in-going current that it is consumed at the proper point, thereby assisting combustion when not in excess, yet indicating its presence by an extension of the flame. Under such circumstances, it is the duty of the miner to lower the wick, which may be done easily in these lamps by means of a rack and pinion, and thus diminish the flame; otherwise, as the gas becomes in excess, the flame will itself decline, and ultimately expire from want of proper sustentation. This plan is shown in figure No. 2, which is nearly full size, with gauze 1296 meshes per square inch. Figures No. 1 and No. 3 show, upon the same principle, how the Lamp may be fed with heated oil, whereby less of it is consumed, while increased brilliancy of light is obtained. Figure No. 3 shows also the application of the dioptric lens. The gauze in all these Lamps extends from the top to the bottom of the frame, and is stronger, finer, and more secure than the ordinary gauze of the Davy Lamp, as there is double the number of holes in it, which may be increased to from five to ten thousand and upwards in each square inch, and still combine perfect security with abundance of light

ADVANTAGES PECULIAR TO THIS LAMP.

It is easily cleaned and kept in repair.

It is impossible for the workmen to light their pipes by sucking the flame through the gauze.

The intensity of the light can be regulated at pleasure, so as to economise the oil when there is not much light required.

It is impossible to explode the gas through the gauze.

The following gentlemen have expressed their approval of Mr Hall's Lamp:—

Mr N. Wood, President of the North of England Institute of Mining Engineers.
,, Thos. John Taylor, Mining Agent to Duke of Northumberland.
,, Thos. Sopwith, Chief Mining Agent to W. B. Beaumont, Esq., M.P., and Commissioner to the Crown under the Dean and Forest Act.
,, Wm. Anderson, Mining Agent to Earl of Lonsdale, &c., &c.
,, Hy. Morton, Chief Agent to the Earl of Durham.
,, Geo. Elliot, Mining Agent to Marquess of Londonderry.
,, R. Heckels, Mining Agent to Earl of Durham.
,, Thos. Wood, Managing Owner at Ludworth and Thornley Collieries.
,, John Dobson, Architect, Newcastle-on-Tyne.
,, John Robson, Managing Owner for several Collieries.
,, Edw. Potter, Do. Do. Do.
,, Wm. Barkus, Mining Agent, Gateshead Fell, do. do.
,, M. Liddell, Mining Agent for Gosforth and Mickley Collieries.
,, Jas. Easton, Mining Agent for Hebburn and Gateshead.
,, Wm. Armstrong, Mining Agent for Lord Howden, Wingate Grange, and Castle Eden Collieries.

Mr Thos. E. Forster, Mining Agent for South Hetton, Seaton Delaval, &c.
,, Thos. Storey, C. E., St. Helen's, Auckland.
,, P. S. Reid, Viewer, Pelton Colliery.
,, G. C. Greenwell, Manager of the Countess of Waldegrave's Coal Mines, at Radstock, near Bath, and late Mining Agent at Marley Hill and other Collieries.
,, Robt. Simpson, Managing Agent to the Stella Coal Company, at Townley and Whitefield Collieries, Ryton, County of Durham.
,, Wm. Watson, Viewer, Newcastle.
,, Hy. Watson, Manufacturer of Safety Lamps, &c.
,, J. Abbot & Co., Do. Do. Do.
,, Wm. Hunter, Mining Agent for several Collieries. "You have obtained two great desideratums, increased light and perfect safety."
,, Dr. Richardson, Newcastle-upon-Tyne.
,, W. G. Armstrong, F.R.S., Do.
,, Robt. Hawthorn, Engineer, Do.
,, Wm. Hawthorn, Do., Do.

Also, two others, formerly pitmen. One of these is now a viewer; the other, when a boy, was employed to work a steel mill, which only gave sparks instead of flame, to light the hewers at their work in the mine at Wallsend Colliery.

At the Miners' Conference, held at Bolton on the 6th inst., (at which 40 delegates were present), the Chairman, through Mr Jude, brought before the delegates the Improved Safety Lamp of Mr T. Y. Hall, Newcastle. The Lamp was much admired, and the delegates promised, on returning to their several localities, to make its merits known to their employers and fellow-workmen.

SHORT DESCRIP

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OF

Mr. T. Y. Hall's Patent

Mines, at Radstock,
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wnley and Whitefield

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of an inch in depth, and two inches below the top of the Lamp,
wards between a sheathing of glass surrounding the lower portio
tube or chimney, into a chamber or vault in the oil-pan, having
which the cool air returns upwards, and is directed against t
chimney, which assists in consuming the smoke and guides th
chamber, which is formed by a stopper extending from a brass
inner tube, whence it makes its exit in all directions through doub
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may be fed with heated oil, whereby less of it is consumed, whil
is obtained. Figure No. 3 shows also the application of the dio
these Lamps extends from the top to the bottom of the fram
more secure than the ordinary gauze of the Davy Lamp, as the
holes in it, which may be increased to from five to ten thousan
inch, and still combine perfect security with abundance of light

e obtained two great

e other, when a boy,
f flame, to light the

ich 40 delegates were
the Improved Safety
nd the delegates pro-
vn to their employers

ADVANTAGES PECULIAR TO THIS L

It is easily cleaned and kept in repair.
It is impossible for the workmen to light their pipes by suc
gauze.
The intensity of the light can be regulated at pleasure, so a
there is not much light required.
It is impossible to explode the gas through the gauze.

The following gentlemen have expressed their approval of Mr

Mr N. Wood, President of the North of England Institute of
,, Thos. John Taylor, Mining Agent to Duke of Northumb
,, Thos. Sopwith, Chief Mining Agent to W. B. Beaumon
sioner to the Crown under the Dean and Forest Act.
,, Wm. Anderson, Mining Agent to Earl of Lonsdale, &c.,
,, Hy. Morton, Chief Agent to the Earl of Durham.
,, Geo. Elliot, Mining Agent to Marquess of Londonderry.
,, R. Heckels, Mining Agent to Earl of Durham.
,, Thos. Wood, Managing Owner at Ludworth and Thornley
,, John Dobson, Architect, Newcastle-on-Tyne.
,, John Robson, Managing Owner for several Collieries.
,, Edw. Potter, Do. Do. Do.
,, Wm. Barkus, Mining Agent, Gateshead Fell, do. do.
,, M. Liddell, Mining Agent for Gosforth and Mickley Coll
,, Jas. Easton, Mining Agent for Hebburn and Gateshead.
,, Wm. Armstrong, Mining Agent for Lord Howden, Win
Collieries.

32

ERRATA UPON SAFETY LAMPS.

Page 5.—After "as in the lamp of Upton and Roberts" add "although my lamp admits of a similar modification, if thought desirable.

Page 6, line 24.—For "before" read "any other."

Page 8, line 20.—Strike out the words after "making" to the end of the sentence, and read "the oil-pan at the top of the lamp, which will cause the oil to become heated."

Page 13, line 1 in note—For "less" read "more," and add to the note "my lamp proves, on the contrary, that 5,000 to 1,000 holes per square inch may be used with perfect safety, and produce a good light."

Page 14, lines 22 and 23.—For "condensed by the lens" read "rendered capable of."

SHORT DESCRIP

al, &c.

OF

Mr. T. Y. Hall's Patent

Mines, at Radstock,
eries.
wnley and Whitefield

The principal improvements in these Lamps consist of arrang obtained two great
combustion, the consumption of smoke, and an increase of lig
from explosions of gas, so destructive to human life in coal minin

gauze.

The intensity of the light can be regulated at pleasure, so a
there is not much light required.

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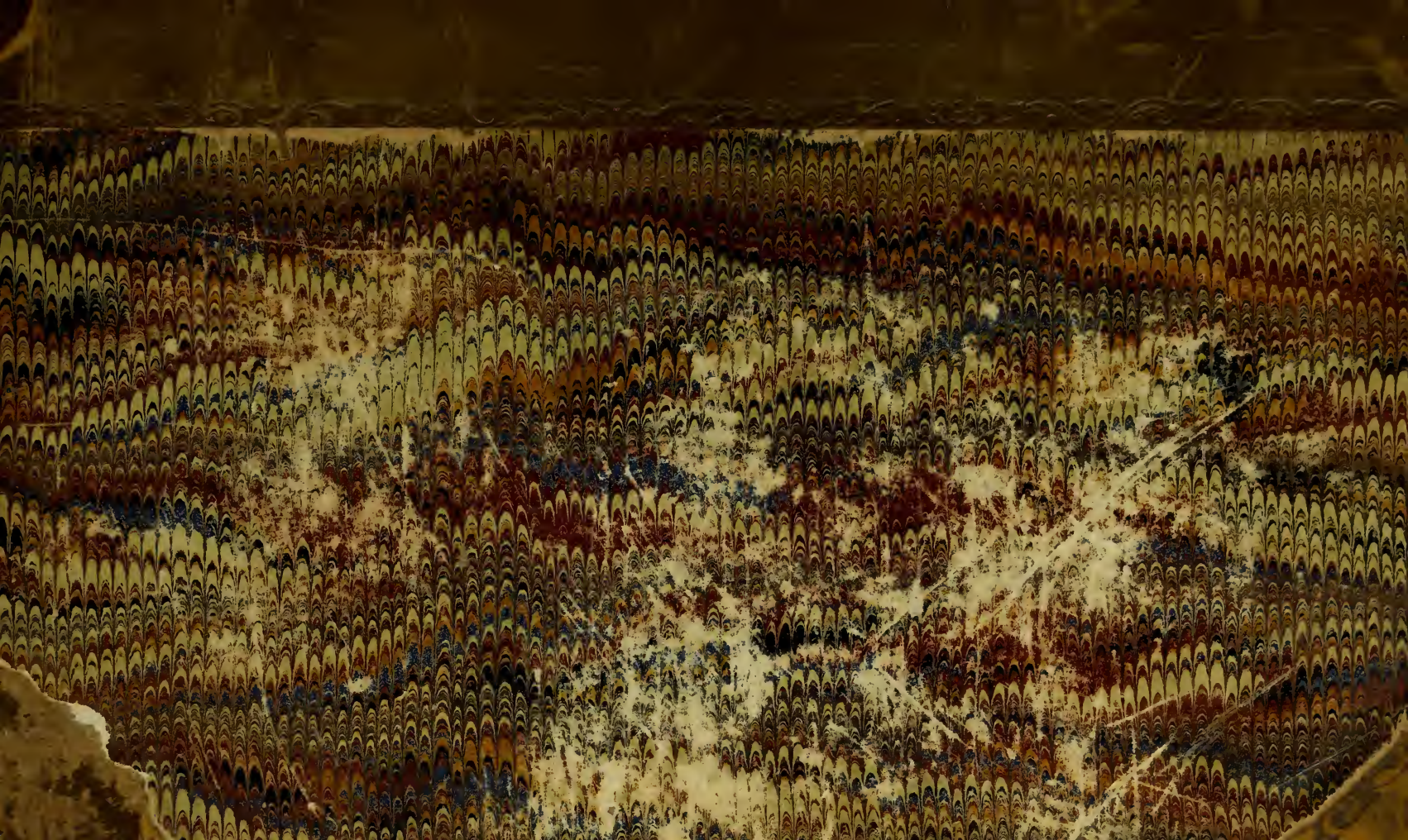
32